THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. IX.

No. X.—OCTOBER, 1902.

ORIGINAL ARTICLES.

I.—Note on a Pliocene Vertebrate Fauna from the Wadi-Natrun, Egypt.

By C. W. Andrews, D.Sc., F.G.S., British Museum (Natural History).

(PLATE XXI.)

AMONG the collections received from the Egyptian Survey for determination is a number of vertebrate remains, chiefly mammalian, from the Wadi-Natrun, whence they were obtained by Captain Lyons, the Director-General of the Survey, and by Messrs. Beadnell and Blanckenhorn, members of his staff. Last year, on my return from Mogara with Mr. T. Barron, I was able to collect for a few hours on the hill called Gart-el-Moluk, from which most of these fossils were obtained, and found a few additional fragments. Finally, Dr. Studer, of the Berne Museum, has very kindly lent me the collection he received from the same locality, and has himself described in some detail.[1] I believe, therefore, that a great part of the specimens from this locality are now in my hands. Unfortunately in most cases the remains are in a very fragmentary condition and little can be made of them, but there are a few well-preserved teeth and limb bones which indicate the existence of a fauna of considerable interest, and are sufficient to show that the locality will probably yield good results to a systematic search. At present the collections include remains of a small *Hippopotamus*, a *Hipparion*, a small pig-like animal, and various Antelopes. In the present note I propose to give a short account of the more important of these specimens.

Hipparion. (Pl. XXI, Fig. 1.)

Hipparion is represented in the collection by a very well-preserved left upper premolar (?p.m. 4). The enamel is extremely complexly folded, and in this respect the tooth closely resembles that of

[1] "Ueber fossile Knochen vom Wadi-Natrun, Unteregypten": Mittheil. d. Naturforsch. Gesellschaft in Bern, 1898 (1899), p. 72.

Hipparion gracile Kaup, from the Pliocene of Epplesheim. It differs, however, from most specimens of that species in having its inner column more laterally compressed. In the form of the inner column *Hipparion Theobaldi*, from the Siwalik Hills, approaches the Egyptian form very nearly, some of the teeth figured[1] by Mr. Lydekker being almost identical in structure with the specimen here described. In the absence of more complete material it will be best to refer our specimen to the widely spread species *Hipparion gracile*, at the same time drawing attention to the fact that in some respects it resembles *H. Theobaldi*, and, like it, probably represents a somewhat later stage in the evolution of the group, the form of the inner column being rather more like that of *Equus* than is the case in the European species.

The tooth from Wadi-Halfa described by Lydekker (Quart. Journ. Geol. Soc., vol. xliii, 1887, p. 161) is that of a true *Equus*, near *E. sivalensis*, and the deposits from which it came are probably Upper Pliocene or early Pleistocene age.

The dimensions of the tooth now described are: length 29, width 28, height of crown 38 mm.

Hippopotamus hipponensis, Gaudry. (Pl. XXI, Figs. 2–5.)

Among the best preserved specimens are three teeth of a small *Hippopotamus*, which, for reasons given below, may be referred provisionally to the above-named species. The specimens are, a lower premolar, probably p.m. 3 (Pl. XXI, Fig. 2), and two upper posterior molars (Figs. 3–5), one of which is quite unworn.

The species *H. hipponensis* was founded by Gaudry[2] on teeth occurring in Pliocene beds near Bone in Algeria. The premolar is stated to be especially characterized by a very prominent postero-internal cusp. The molars are not figured, but it is stated that they do not present any important peculiarities. From this it would appear that the sides of the columns were probably grooved so as to give a trefoil pattern in wear, for the absence of such a marked characteristic of most *Hippopotamus* molars could not well have escaped Professor Gaudry's notice. For this reason it seems probable that the teeth from the Pliocene of Casino, described and figured by Pantanelli[3] as those of *H. hipponensis*, may in fact belong to another and probably earlier species, since in them the trefoil pattern is wanting, or, at least, obscure. The animal which Pomel[4] refers to *H. hipponensis*, without giving any valid reasons for his determination, seems to be quite different and is of Pleistocene age.

For the present it will suffice to refer the specimens to Gaudry's species, and defer more detailed consideration until further material is available.

[1] Lydekker, "Siwalik and Narbada Equidæ": Mem. Geol. Surv. India, Palæontologia Indica, ser. x, vol. ii, pt. 3 (1882), pl. xiii, fig. 1.

[2] Bull. Soc. Géol. France, ser. III, vol. iv (1876), p. 501, pl. xviii.

[3] Pantanelli, "Sugli strati Miocenici del Casino (Siena)": Mem. R. Accad. Lincei (3), vol. iii, p. 309, pl. iv, figs. 1–7 (1879).

[4] Pomel, "Carte Géologique de l'Afrique — Paléontologie": Monographie No. 8, Les Hippopotames, p. 9; Algiers, 1896.

The premolar is extremely like that figured by Gaudry in the paper referred to. The form of the cingulum and of the postero-internal cusp, as well as the sculpture of the enamel, are almost identical. In these points also some premolars of *H. sivalensis* are very like our specimen, and in *H. liberiensis* this prominent postero-internal cusp is regularly developed on the lower premolars. The form of this tooth is well shown in Fig. 2. It is much larger than the corresponding tooth in *H. liberiensis*, and is about the same size as some specimens of the premolars of *H. sivalensis*. Its width is 19 mm., its length 32 mm.

Of the two upper molars, one (m. 3) is quite unworn. This specimen is shown in Figs. 3 and 4. The cingulum is very well developed, particularly on the anterior border, and at either end of the transverse valleys there are a number of tubercles which seem also to belong to the cingulum. The anterior pair of cusps are higher than the posterior, and the inner stand slightly above the outer. The sides of the columns are pinched in by vertical grooves on their anterior and posterior faces (see Figs. 3, 4, and 5), so that each column shows the usual trefoil pattern as soon as wear has removed the summit. In this these teeth differ from those figured by Pantanelli, and also from those of *H. liberiensis*, in which the trefoil is imperfectly developed. The teeth, moreover, are more brachydont than those of *H. amphibius* or *H. liberiensis*, i.e. the height of the cusps is rather less in proportion to the other dimensions of the teeth than in those species, and the longitudinal valley is rather deeper. The enamel is thickly sculptured by a series of more or less vertical grooves, and there is also a very fine horizontal striation, best shown on the cingulum and near the base of the crown (see Fig. 3).

The other molar (m. 2, Fig. 5) belonged to a somewhat smaller individual. The cingulum is strongly developed all round and sends spurs into the openings of the transverse valley. Wear has commenced, and is most marked on the antero-internal cusp; the pattern is shown in Fig. 5, where it will be seen that indications of the trefoil pattern are already noticeable. Wear is also well marked on the inner faces of the transverse valley, the cusps of the lower molar having worked between those of the upper. In this tooth also the slightly more brachydont condition is apparent.

The dimensions of the teeth figured are :—

	Length.	Width.	Approx. height of crown.
p.m. 3	32 mm. ...	19 mm. ...	31 mm.
m. 2	36 ,, ...	35 ,, ...	27 ,,
m. 3	39 ,, ...	39 ,, ...	33 ,,

A number of limb bones referable to *Hippopotamus* have been determined by Dr. Studer (*op. cit. supra*). One of these specimens is a small humerus (see figure in text) which no doubt belongs to the present species. It is very closely similar to the humerus of *H. sivalensis*, with which I have compared it, but at the same time is somewhat smaller. The presence of an irregular perforation in

the floor of the olecranon fossa seems to be of little importance, and may be the result of accident. The form of the *condylus internus* is like that of the Indian species. The width of the distal end of this specimen is 97 mm.; the width of the lower end of the shaft is 40 mm. The proximal end of the conjoined radius and ulna and the distal end of the ulna and part of the radius likewise differ from the corresponding parts in *H. sivalensis* in little besides their somewhat smaller size.

Distal half of humerus of *Hippopotamus hipponensis*, Gaudry.
$\frac{1}{3}$ nat. size.

The femur (see Studer, *op. cit.*, p. 75) differs from other *Hippopotamus* femora with which it has been compared in having a shorter neck, so that the rounded head is less pedunculate than is usual in the genus. This bone seems to have belonged to a larger individual than most of the others.

There are two calcanea in the collection which, though worn and broken, are certainly those of a *Hippopotamus*. One of these specimens is much larger than the other, and, like the femur above mentioned, may indicate either that the range of individual variation in size was very considerable or that there was a second species; the second alternative seems the less probable; the length of the larger is approximately 16·5 mm. A phalangeal bone is rather more slender than in other species of *Hippopotamus*. Its length is 60 mm., the width of its proximal end is 34 mm., the height of ditto 25 mm.

Sus, sp. (Pl. XXI, Fig. 6.)

The third lower molar of a small pig seems to be the only fragment of that animal found in the collection. The form of this specimen, which belongs to the right side, is shown natural size in Fig. 6. It will be seen that it is a simple type of tooth with

few accessory cusps and a short talon; the front of the tooth is incomplete, the antero-internal cusp having been broken away; the antero-external cusp is oval in outline. Behind the anterior pair of main cusps and closely adherent to the inner one is a small tubercle (the hinder tubercle of the anterior crescent), and immediately behind this a rather larger tubercle occupying the middle of the transverse valley (this is the 'central-hügel' of Stehlin and the tubercle marked 'e' by Lydekker). Of the hinder pair of main cusps the inner is the smaller and the higher; behind them, again, is a large median cusp (the 'verbindungs-hügel' of Stehlin,[1] 'a' of Lydekker's[2] figures). The talon is short and simple, consisting of a main cusp ('b' of Lydekker) nearly in the middle line, a smaller one ('c' of Lydekker) internal to this, and smaller tubercles opposite the outer ends of the 'verbindungs-hügel': these last small cusps seem to belong to the cingulum, which is not otherwise represented.

The most notable character of this tooth is its very small size. Its length at the base of the crown is 24 mm., at the summit of the crown 22 mm.; its greatest width was approximately 13 mm. It is therefore longer than the corresponding tooth of *Sus punjabiensis* (16 mm.), and at the same time considerably smaller than some specimens in the British Museum referred to *Sus hysudricus*, which in many respects it resembles closely. As Stehlin has pointed out, however, it is very doubtful whether all the specimens referred to *S. hysudricus* really belong to one species; it is the *Potamochœrus*-like form figured by Lydekker (*op. cit. supra*, pl. viii, figs. 2 and 3) which comes nearest to our Egyptian species. With such scanty material as is available at present it is impossible to determine definitely the systematic position of this animal, but it seems most likely that it comes somewhere between the earlier *Palæochœrus* and the later *Sus hysudricus*, or perhaps *Potamochœrus*. The dwarf forms *Sus punjabiensis*, *Sanitherium Schlagintweiti*, and *Porcula salviana*, which seem to be closely allied to one another, may also be related, but are still smaller.

Remains of Ruminants are represented by the teeth, horn-cores, and fragments of limb bones of various antelopes.

Hippotragus ? *Cordieri*, De Christol. (Pl. XXI, Figs. 7 and 8.)

The most interesting of these specimens is an unworn left third lower molar. After comparison with the teeth of many antelopes it was found that this tooth agrees almost exactly in pattern with an uncut third lower molar of a young individual of *Hippotragus niger*, but that at the same time the crown is much more brachydont. Thus, in the recent species the length of the tooth to the height of the crown is as 29 to 43, in the fossil the proportion is as 31 to 36.

[1] Stehlin, "Ueber die Geschichte des Suiden-Gebisses": Abhand. Schweiz. Palaeont. Gesellschaft, vol. xxvi (1899), p. 30.

[2] Lydekker, "Siwalik and Narbada Bunodont Suina," pl. viii, etc.: Palæont. Indica, vol. iii (1884).

The difference is even more strongly marked than would appear from the measurements, because in the fossil the columns are thicker than in the recent species, and the whole tooth has a much more massive aspect. The increase in height seems to have affected the anterior portion more than the posterior, the much greater length of the antero-internal accessory column being particularly noticeable. In the fossil the accessory inner columns lying between the anterior and posterior lobe and between the latter and the talon are very small, the posterior one in fact being a mere rudiment; in the recent animal these have increased greatly in size, and their height is much greater, not only absolutely but also relatively as compared with the main columns. The enamel on the inner face of the tooth is more sculptured than in the recent species, being covered with irregular grooves which give it a surface like that common in teeth of the Giraffidæ. The enamel of the outer face is almost smooth.

A last lower molar of an antelope from the Pliocene sands of Montpellier, figured by Gervais (Zool. et Pal. françaises, 2nd ed., 1859, pl. vii, figs. 8, 8*a*), is closely similar to the Wadi-Natrun tooth; it is referred to *Antilope recticornis*, which Gervais regards as synonymous with *A. Cordieri* of De Christol. This animal has also been described by Forsyth Major (Atti Soc. Tosc., vol. i, 1875, p. 231) from the Lower Pliocene of Casino. The fact that this species is referable to *Hippotragus* was pointed out by Sir Victor Brooke in 1873 (Proc. Zool. Soc., p. 551). A species of *Hippotragus* has also been described by Lydekker from the Pliocene of the Siwalik Hills (Palæont. Indica, vol. iv, pt. 1, 1886, p. 10, pl. ii, figs. 4, 4*a*). It is very likely that the Egyptian form, when better known, will turn out to be a distinct species, but it is here referred provisionally to the widely distributed *Hippotragus Cordieri*, De Christol sp. (*H. recticornis*, Marcel de Serres sp.), above noticed.

The collection also includes a greatly worn molar which agrees closely with the upper milk-molars of *Hippotragus*, and may therefore be assigned to the same species. A horn-core in the collection of the Berne Museum probably also belongs here. It is raised on a prominence of the frontal, enclosing a large sinus which extends upwards into the base of the core itself. It is nearly circular in section, but is so much broken that its form and length cannot be clearly made out; it must have been much shorter than in an adult individual of *Hippotragus niger*. This specimen has been described by Professor Studer, who regards it as that of an antelope related to *Oryx*. There are also some fragments of limb bones, including portions of a femur, a tibia, and a metatarsus; the last belonged to a rather smaller animal than *H. niger*.

The other molar of a Ruminant, figured on Pl. XXI, Fig. 9, is a remarkably hypselodont tooth, resembling in many respects that of a modern goat. It is the last lower molar of the left side and is somewhat incomplete, the antero-external column being lost. It is greatly compressed from side to side, the talon in particular being extremely narrow, at least towards its summit. The length of this

tooth is 26 mm., its height 41 mm. I have been unable to find any form closely similar to this, but it seems to resemble some hypselodont teeth figured by Rodler & Weithofer ("Die Wiederkauer der Fauna von Maragha," pl. iv, fig. 5: Denkschr. k. Ak. Wissenschaften, Wien, vol. lvii, 1890, p. 770). The animal was no doubt an antelope, and probably a large gazelle-like form. A horn-core which is somewhat laterally compressed, especially on its outer side, probably belongs to this animal. Its curves are like those of some gazelle horns.

The collection also includes remains of crocodiles, *Trionyx* and other Chelonians, and fish.

The stratigraphy of the beds in which these bones were found is described in detail by Blanckenhorn in "Neues zur Geologie und Palaeontologie Aegyptens," pt. iv (Zeitschr. d. Deutsch. geolog. Gesellschaft, 1901, p. 301), to which reference may be made for further information on this point. He regards the beds as Lower Pliocene, which agrees well with the conclusions arrived at from the consideration of the mammalian fauna, the horizon of which is probably a little later than that of Casino, and is, therefore, either late lower or early middle Pliocene.

II.—*Eophrynus* and Allied Carboniferous Arachnida.

By R. I. Pocock, F.Z.S., of the British Museum (Natural History).

Part I.

Introduction.

FOR the opportunity to study the interesting Carboniferous Arachnid forming the subject-matter of the following pages, I am indebted to the kindness of Dr. Henry Woodward, F.R.S., who recently placed in my hands for that purpose a very perfect gutta-percha cast, and a good, though less complete one, in plaster, of the original fossil specimen, which was unfortunately not available for examination in its natural form.

The typical species of the genus *Eophrynus* was described and figured from an imperfect specimen by Buckland in 1836. Dr. H. Woodward in 1871 correctly assigned this fossil to the Arachnida. Buckland regarded it as the remains of a coleopterous insect, and named it *Curculioides prestvicii*. The genus *Curculioides* also contained a species named *ansticii*, the systematic position of which is still in doubt.[1]

[1] Four pairs of appendages are represented as attached to the anterior portion of the body, to the front border of which a separate transverse sclerite was apparently articulated. Buckland regarded this sclerite as the head, and the appendages as the antennæ and three pairs of legs of a beetle. No segments are described in connection with the abdomen, but, judging by the figure, this region was furnished with a large circular anal orifice. Scudder (Proc. Amer. Acad. Arts and Sci., vol. xx, 1882, p. 17) provisionally placed this species in the Arachnida, near *Architarbus*. I suggest that it may be an Arachnid allied to the recent *Cryptostemma*. In the latter the large circular and gaping anus is a very marked feature; there is a movable sclerite jointed to the anterior border of the carapace and completely concealing the mandibles; the appendages of the second pair are tucked beneath the prosoma when at rest, so that from its dorsal side the animal exhibits only four pairs of limbs. In these three features *Cryptostemma* resembles *Curculioides ansticii*.

Thirty-five years later a second and remarkably perfect specimen of *C. prestvicii*, which set at rest the question of the Arachnidan affinities of the species, was discovered in the clay ironstone of the Dudley Coal-measures. Upon the species represented by this specimen Dr. Woodward based the genus *Eophrynus*, leaving *ansticii* by elimination as the type of *Curculioides*.

Unfortunately, owing to certain errors committed by the artist, the figure and description of the fossil are discrepant in various particulars. In other cases important structural points are obscured by heavy shading. These blemishes in the illustration made the subsequent determination of the true structure and taxonomic position of *Eophrynus* a matter of considerable difficulty. A far more accurate figure was subsequently drawn by Miss G. M. Woodward, under Dr. Woodward's supervision, and printed in the "Guide to the Fossil Invertebrata in the Department of Geology and Palæontology in the British Museum" (Natural History), 1897. I am indebted to Miss Woodward for the care and skill shown in the preparation of the figures accompanying Part II of this article, which were taken partly from my sketches representing my conception of the features exhibited by the fossil. Since the cast of *Eophrynus* is the only representative of this group of Carboniferous Arachnida that I have been able to see, I have been compelled to trust to the accuracy of the figures and descriptions of other authors for information regarding allied forms.

The subject-matter of this essay may be conveniently divided into three sections: (1) The morphology of *Eophrynus*; (2) the classification of *Eophrynus* and its allies; (3) the taxonomic position of the Anthracomarti.

1. The Morphology of *Eophrynus*.

The synonymy of *Eophrynus prestvicii* is as follows:—

Eophrynus prestvicii (Buckl. sp.).

Curculioides prestvicii, Buckland: Bridgw. Treatise Geol. and Mineral., vol. ii (1836), p. 76, pl. 46″, fig. 2 (2nd edition, 1837).

Eophrynus prestvicii, H. Woodw.: Geol. Mag., 1871, pp. 386–388, Pl. XI; and of subsequent authors.

The *carapace* is unsegmented. It is narrowed anteriorly, its posterior width exceeding its length. Its median area from the anterior almost to the posterior border is raised into a broad longitudinal axial elevation, divided superficially into ridges and lobes by transverse and longitudinal grooves. Two transverse constrictions which cross its dorsal surface divide it into three subequal portions—an anterior, a median, and a posterior. The last is laterally crested and impressed mesially and behind by a longitudinal groove, which appears to correspond to the median muscular impression or fovea present upon the carapace in some other orders of Arachnida. The median and anterior portions are divided by two longitudinal grooves into a central and two lateral crests. The central crest of the median portion is the highest point of the carapace. It bears a pair of oval pits. The anterior portion slopes obliquely downwards and forwards to its narrowed but bluntly

convex extremity. The elevated areas just described are roughened with coarse, sometimes anastomosing, granules. This elevated portion of the carapace occupies rather more than the median third of its area. Behind and on each side of it the carapace projects horizontally and exhibits a coarse sculpturing of pits and anastomosing ridges. The area behind the elevation is short, and marked with a narrow transverse recurved crest which equals the width of the posterior end of the elevation; the area at the sides is impressed with two grooves passing externally into marginal notches which give rise to the trilobed appearance of this region. The three lobes overlie the basal segments of the second, third, and fourth legs (fourth, fifth, and sixth appendages), the grooves and marginal notches corresponding to the interspaces between them and representing, no doubt, the radiating grooves of the carapace of the Araneæ and Pedipalpi, which are known to be the external indications of the points of attachment of the dorsal muscles uprising from the entosternite. Below the lobes the edge of the carapace appears as a narrow but high ledge which apparently rests upon the coxæ of the appendages. The anterior portion of the carapace at the sides and in front of the median elevation where the first and second pairs of appendages emerge is unfortunately somewhat crushed, and the exact details of its structure are difficult to trace. It is noticeable, however, that there is no evidence of the presence of a frontal sclerite articulated to the fore border of the carapace, such as is found in *Cryptostemma* and is alleged by Haase to be present in *Kreischeria*. Apart from the oval pits above described I can find no trace of any structures resembling eyes, though it is almost certain these organs were present in the living animal, considering the size to which it attained.

The *sternal area* of the prosoma is longer than wide, but considerably wider than that of all existing orders of terrestrial Arachnida with the exception of the Araneæ, Amblypygous Pedipalpi, and Acari. As in the Amblypygi (e.g. Phrynidæ), it was apparently membranous at the sides, but is furnished mesially with an anterior and a posterior sternal plate. The latter is short and narrow, and in the specimen has been displaced from the middle line so as to lie in front of the inner extremity of the coxal segment of the sixth appendage of the left side. The anterior plate, on the contrary, has been thrust over towards the right side of the specimen. It is much broader and longer than the metasternite, and lies between, though not in contact with, the coxal segments of the third, fourth, and fifth pairs of appendages (i.e., the first, second, and third walking-legs). It is somewhat deeply bi-emarginate laterally, the emarginations corresponding to the convexly rounded proximal ends of the coxæ of the fourth and fifth appendages. Its anterior portion is lanceolate, and extends forwards between the coxæ of the appendages of the third pair almost as far as those of the second pair or palpi. No trace of a prosternal plate corresponding to the last-mentioned appendages is discernible.

With regard to the structure and relations of the large sternal

plate described above, there is, I think, no possibility of error, so clearly defined is the sclerite. But concerning the smaller and posterior sternal sclerite there is room for doubt. Assuming, as I have assumed, that it is part of the sternal exoskeleton, its distinctness from the anterior plate may be due to fracture and subsequent displacement. But in the specimen before me, it appears as a forwardly directed process from the inner edge of the coxa of the adjacent appendage. Since no corresponding piece, however, is traceable upon the better preserved coxa of the opposite side, I have felt justified in assuming that it is not part of the appendage, but part of the sternal area.

Of the appendages of the first pair (*mandibles, cheliceræ*), that of the left-hand side only is exposed. From the dorsal aspect traces of two segments are to be seen projecting forwards from the anterior end of the carapace, the proximal being noticeably longer than the distal. From the ventral aspect there is visible a skeletal piece which, from its position, appears to underlie the distal segment. It is obliquely truncated in front and pointed behind, the pointed portion being marked with a longitudinal groove which may represent the divisional line between the two prongs of a pincer. The whole structure, however, is too ill-defined to allow of any positive statement on the question. So far as an opinion can be formed, however, it appears to me evident that these appendages more nearly resembled those of Opiliones than those of any other order of terrestrial Arachnida.

The appendages of the second pair (*palpi*) are remarkably long as compared with those of the Opiliones Palpatores, which in a general way they resemble. The femur is as long as that of the third leg, and the tibia, which is very slender and unspined, is almost as long as the femur and twice as long as the slender tarsus, which bears a single claw. The joint between the patella and tibia is indistinctly defined. The basal segments are crushed, but they appear to meet in the middle line in front of the sternal area and to be furnished with a large forwardly directed maxillary lobe.

In the remaining appendages (the four pairs of *legs*) the coxæ are arranged at the sides of the sternal area, exhibiting a slightly radial disposition. Judging by the narrow spaces separating the coxæ on each side from one another, these segments were freely movable, like those of the Araneæ and Amblypygous Pedipalpi. The proximal ends of the coxæ of the first pair are inclined upon the margins of the lanceolate anterior end of the sternum.

Those of the fourth pair are considerably larger than the others, diverge from each other at an angle of 90°, and almost meet in the middle line behind the sternal area. Across the proximal end of each and over the narrow triangular space between them runs a distinct, apparently granular ridge, the significance of which I am unable to interpret.

So far as the rest of the segments are concerned, it is regrettable that the tarsus and protarsus are preserved only in one instance, namely, in the first leg of the left side. The segments are subequal

in length, and the tarsus, which is attenuated and unjointed, is tipped with a single claw. The tibia also of this appendage is faintly indicated; and a large part, perhaps the whole of this segment, is preserved on the third leg of the right side and the fourth of the left side. In all cases it appears to be a relatively stout and short segment, but little, if at all, exceeding the patella in length. The patella of the fourth leg is about half as long as the femur; that of the other legs, rather more than half. The femora of the first, second, and third pairs are shorter than the carapace; that of the fourth, which is lightly concave on its post-axial side, longer than the carapace. The trochanters of all the legs, like those of the palpi, are well defined on the ventral side. They are large segments, constricted in their basal half, and evidently capable of very free movement upon the coxæ. The legs progressively increase in length from the first to the fourth pairs. Their dorsal surface is granular, pitted, and frequently longitudinally grooved.

The *opisthosoma* (*abdomen*) anteriorly equals the prosoma in width. It expands posteriorly towards the fifth or sixth somite, is widely rounded along its hinder border, and at its greatest width is almost as broad as long. The lateral portions of the terga are expanded into transversely suboblong, closely fitting laminæ, separated by an apparently membranous joint from the main central portion of the segment. The posterior border of the terga in the hinder half of the dorsal surface becomes gradually more and more recurved from before backwards, the recurvature of the penultimate tergum being so great that the posterior edges of its lateral plates lie nearly parallel to the long axis of the opisthosoma. The terga are covered with coarse granules and tubercles. Apart from the granules and less conspicuous tubercles, each tergum is typically furnished along its posterior border with a transverse row of six large tubercles, four on the central part of the tergum and one on each of the lateral plates. Of the former, two are close to the middle line, the other close to the joint of the lateral plate. In front of the two central tubercles there is a pair of about half their diameter which meet in the middle line, and on the posterior border between the two centrals a much smaller tubercle is present.

As was stated in the original diagnosis, *nine* somites, defined by transverse grooves, are traceable on the dorsal side. The lateral borders of the first are ill-defined, and of the second also on the right-hand side, owing apparently, in part at least, to the up-pushing of the coxa of the sixth appendage. The first, however, although a little longer, seems to be narrower than the second, and shows no evidence of the presence of lateral laminæ. The central and lateral tubercles of its median portion are normally developed.

The second tergal plate exhibits on the left-hand side a fully formed lateral lamina, which apparently projects forwards on each side of the first towards the posterior angles of the carapace. The tubercle on the posterior angle of this lamina corresponds exactly

with that on the following terga, but the remaining large tubercles characteristic of the laminæ and of the central portion of these segments are almost undeveloped on the second. A median pair a little larger than the rest that stud its surface, and one on the left-hand side, are all that remain to represent the principal tubercles. The posterior border of the plate, moreover, though marked by a series of granules, is less well defined and more sinuous than that of the other terga. An examination of the plate, in fact, forcibly suggests that it is in process of fusion with that of the third somite. Indeed, were it not for the distinctness of the lateral lamina on the left-hand side, it might be interpreted as the anterior portion of the latter somite. This interpretation, however, leaves unexplained the distinctness of the lamina in question, and of the transverse groove that is continuous with its posterior angle, and traverses the dorsal surface from side to side in a direction parallel with that of the recognized tergal sclerites; also it carries with it the conclusion that the second tergum is of exceptional size, namely, three times as long as the first and twice as long as the third.

On the whole it appears to me that the view here adopted, that nine tergal plates are present on the upper side of the opisthosoma, and that the second is reduced in size and modified by the suppression of its large tubercles, possibly also by partial fusion with the third, is more in keeping with the facts exhibited than the alternative hypothesis that has been already discussed.

This view of the existence of nine visible terga on the dorsal side is opposed to that of Haase, Stur, and Ammon, who recognize only eight such plates in certain allied Carboniferous Arachnids they have examined. In the case of *Eophrynus salmi*, Stur declares the dorsal side to be divided by seven sulci into eight plates. His drawing, however, of the anterior portion of the opisthosoma in his species is by no means conclusive on this point. In the first place, there is a want of definition about this area, due, perhaps, to the bad state of preservation of the fossil; in the second place, there is obviously space enough between what are described as the first and second terga for the presence of another plate; in the third place, on the left-hand side nine large segmentally arranged tubercles are represented, whereas, if only eight terga are present, only eight tubercles should be shown.

So, too, with *Anthracomartus palatinus* of Ammon.[1] Eight tergal plates are described. The first is represented as a short plate, as wide as the carapace, laterally attenuated, without laminæ, and fitting into the emarginate anterior border of the second. The latter is large, and its laminæ extend forwards on each side of the first, almost reaching the posterior angles of the carapace; but it is most clearly marked with a transverse and procurved sulcus, defining an area of about the same width and nearly the same size and shape as the first tergal plate. This, I suspect, represents the genuine

[1] Geogn. Jahresf., 1900, pp. 1–4, figs. 1–3.

second tergal plate, perhaps partially or completely fused with the third. If this be so, there will be nine tergal sclerites visible on the upper side of the opisthosoma, at all events in this species of *Anthracomartus*.

Haase's[1] figure of the segmentation of the dorsal side of the opisthosoma of *A. völkelianus* is open to the same interpretation. A distinct, though short and narrow plate is represented between the posterior border of the prosoma and the lightly emarginate anterior border of what he regarded as the first tergite of the opisthosoma. If this hitherto disregarded sclerite be counted as the first, the opisthosoma of the specimen in question presents nine visible terga when regarded from above. This view of the matter reconciles certain differences in the structure of the anterior segments of the opisthosoma in *A. völkelianus* and *A. palatinus*, which the older hypothesis left unexplained.

In the case of *Kreischeria*, again, Haase and Geinitz depict and describe eight terga, and there are only eight rows of tubercles. But between the posterior border of the carapace and what is regarded as the first tergum a narrow sinuous area is figured which may be the tergum of the first genuine somite. Its size and lateral attenuation certainly suggest the first tergite of *Anthracomartus palatinus*; and it further resembles the first plate in *Eophrynus prestvicii* in being embraced at the sides by the lateral laminæ of the second, which are directed obliquely forwards and outwards. If this theory be adopted the differences between the first and second terga in *Kreischeria* and *Eophrynus prestvicii* are very considerable, for in the latter it is the second that is in process of obliteration and has become modified by the suppression of its tubercles, the first remaining normal in these particulars, while in *Kreischeria* the converse holds.

Another view of *Kreischeria*, however, may be entertained. The tergum that Haase regards as the second is much larger than those which he counted as the first and third, and it is possible that it represents two terga, namely, the second and third entirely fused, the process of fusion that is indicated in *E. prestvicii* having been carried to its completion in *Kreischeria*. This supposition gains some support from what is presented in the allied Arachnid *Brachypyge carbonis*, where the second tergal plate is also of large size and may represent the dorsal elements of the second and third, there being only eight terga traceable on the upper side of the fossil. There are reasons, too, for thinking that the first tergite also, although clearly enough defined, is fused to the second large plate in the form just mentioned.

These doubtful points will no doubt be settled by a re-examination of the fossils in question. In any case there appears to me to be no escape from the conclusion that nine tergal plates are visible on the upper side of the opisthosoma in *Eophrynus prestvicii*. As is explained below, the first of these has apparently no sternal

[1] Zeitschr. deutsch. geol. Ges., vol. xlii (1890).

equivalent on the ventral side. It probably therefore represents the tergum of the pregenital somite, and is thus comparable to the first tergite of the opisthosoma in the Pseudoscorpiones and Pedipalpi. The second then will be the tergal plate of the genital somite, like that of the two orders just named.

The smaller size of these two terga as compared with the third, both in *Eophrynus prestvicii* and *Anthracomartus völkelianus* and *palatinus*, recalls what is met with in the Pedipalpi, where also the anterior border of the second is emarginate for the reception of the first.[1]

The third, fourth, fifth, sixth, and seventh terga are, apart from their increasing recurvature, similar in form and structure, except that the median tubercles of the third are more coalesced and form a slightly larger and higher cluster. The eighth also is like those that precede it, except that the posterior lateral angle is produced into a spiniform process. A similar process is present upon the marginal lamina of the ninth. The central area of this plate, however, which is relatively narrow and compressed, is furnished with only two tubercles, representing the lateral pair of the four observable upon the preceding terga. Moreover, the tergum of the ninth somite is continuous posteriorly with a quadrate plate occupying the interspace between the marginal plates of the somite. Since there is no segmental line between this plate and the tergum, the former may be regarded as an expansion of the latter. In this case the ninth somite differs from the rest in being furnished with a median as well as two lateral expansions. This was the view adopted by Haase with regard to *Kreischeria wiedei* and *Anthracomartus völkelianus*, and by Ammon in connection with *Anthracomartus palatinus*. Both these authors, however, were in error, in my opinion, in looking upon the somite in question as the last abdominal somite. For in the figures they have published of *A. völkelianus* and *A. palatinus* the lateral expansions arising from the penultimate, their eighth, tergum are shown to be continuous on the ventral side, with a sternal area behind which at least one complete somite is represented. The same feature is exhibited in the figure of the ventral side of the abdomen of an Arachnid referred by Howard & Thomas to *Brachypyge carbonis*. It is also very manifest in the cast of *Eophrynus prestvicii* now under discussion. Moreover, it appears to me to be an open question whether the terminal median lamina that intervenes between the lateral laminæ of the ninth is an expansion of the tergum of that somite or of the tenth (the preanal) somite. When the opisthosoma of *Eophrynus* is viewed from the underside, the posterior median

[1] Since the pregenital somite is of inconstant occurrence within the class Arachnida, persisting in some orders (e.g., the Pedipalpi, Palpigradi, and Pseudoscorpiones) and obliterated in others (e.g., the Scorpiones, Xiphosuræ, and Solifugæ), I adopt the suggestion of Ray Lankester ("Arachnida" in Encycl. Brit., Suppl., 1902, p. 524) and regard it as a supernumerary somite, counting the genital somite as the first somite of the opisthosoma. The annexed figures [see pt. II] are numbered in accordance with this view of the matter. This fact must be borne in mind in comparing the figures and description.

lamina is seen to extend downwards and forwards to the anal plate and to be continuous on each side with the crescentic sternal sclerite of the tenth somite, which encircles the anal plate and is merely separated from the posterior lamina by a shallow groove on each side.

Here, then, three questions offer themselves for decision :— Does the crescentic sternal plate of the tenth somite belong to the somite of which the anal plate is the tergal representative? Or is the tergal region of the tenth to be found in a part or the whole of the area that lies behind (morphologically above) the anal plate? And is the posterior median lamina an extension of the tergal region of the tenth or of the ninth somite? If an affirmative answer be given to the first question, the number of somites of the opisthosoma will be fixed at ten. If the second question be answered in the affirmative, the number in question will be eleven, the anal plate representing the dorsal sclerite of a somite without sternal element. With regard to the third question, the absence of all divisional line on the dorsal side between the tergum of the eighth somite and the posterior median lamina in *Eophrynus prestvicii*, *Kreischeria wiedei*, and *Anthracomartus völkelianus* points to the correctness of Haase's view that the lamina belongs to the last somite visible on the dorsal side. Again, with regard to the second question, Haase's figure of the ventral surface of the posterior end of the opisthosoma of *A. völkelianus*, and that of the same region in *Eophrynus* (*Brachypyge*) *carbonis* of Howard & Thomas, attest the presence of a distinct annular somite, with sternal, tergal, and lateral regions in front of the anal plate. In *Eophrynus prestvicii* this same somite is recognizable, although its tergal area, lying behind (morphologically above) the anal plate, is very narrow, much narrower indeed than the corresponding area as represented in *Anthracomartus völkelianus*. This somite in *Eophrynus* I count as the tenth. The anal plate then represents the eleventh. This plate has the form of a transversely oval tubercle, and in one of the casts is marked by an incomplete transverse groove which suggests the possibility of its consisting of distinct sternal and tergal elements. If this be the case, the anal somite will resemble that of the Amblypygous Pedipalpi, rather than that of the Cyphophthalmous Opiliones. In other respects the segmentation of the posterior end of the opisthosoma closely resembles that of the last-mentioned group (e.g. of *Stylocellus*), where the last tergal plate, the eighth, visible on the dorsal side, overlaps the ninth; the latter forms a narrow ring round the tenth, of which the tergal element alone persists as the anal plate or valve, its sternal equivalent having apparently disappeared.

I can find only nine sternal plates as compared with the eleven tergal plates. The discrepancy may be accounted for by the disappearance of the sterna of the eleventh or anal somite, and of the first, which has probably atrophied in connection with the enlargement and mesiad approximation of the coxæ of the last pair of appendages, and is no doubt represented by the narrow area between

these segments. Hence the first free sternal plate corresponds to the second tergal. The sternal plates are practically smooth but for the presence of a pair of tubercles on each side of those lying between and including the fourth and eighth. The innermost of these tubercles on each sternite are widely separated from the middle line. Beyond the external tubercles on the fourth, fifth, and sixth sterna there is on each side a conspicuous upstanding ridge, representing perhaps the lateral margins of the plates. Beyond this crest the lateral area of the somite slopes upwards to the margin of the lateral tergal lamina. It is noticeable that the posterior border of the fourth, fifth, sixth, and seventh is elevated, as is the case with the sterna in many Opiliones.

The posterior border of the third sternum is sharply defined, forming a pair of slightly arcuate crests stretching each from near the middle line to the lateral border. The median portion of this plate also presents a distinct and wide pit-like depression which evidently underlies and apparently has a direct connection, possibly in the way of muscular attachments, with the tubercular elevation on the third tergal plate. Since the lateral portions of the posterior border of the third sternum are more decidedly elevated and arcuate than those of the preceding or succeeding sterna, it is possible that the slit on each side they overlie represents the stigma of a respiratory organ. I can find no other structure on the sternal surface of any of the somites that suggests the stigma either of a tracheal tube or a pulmonary sac.

In front of the sternum of the third somite two sterna are, I think, traceable. The anterior of these, which probably belongs to the genital somite, is triangular in form, and projects forwards between the coxæ of the appendages of the last pair. Its posterior border is somewhat irregular, but shows a distinct though small median emargination. The second sternum is narrow. Its posterior border is sharply defined in the middle line, and exhibits a pair of lobate sclerites exactly similar in size and position to those on the second sternal plate of some of the Amblypygous Pedipalpi. There seem to be no reasons for thinking that the genital orifice was situated in front of the first sternal plate as it is in the Opiliones. Presumably it opened behind it as in the Pseudoscorpiones, Pedipalpi, etc.

The type of *Eophrynus prestvicii* gives the following measurements in millimetres :—Total length, 27; length of carapace, 8; its posterior width, 9; length of its median elevated area, 7; posterior width of latter, 4·5; length of opisthosoma, 19; its greatest width (approx.), 17; length of its sternal area from anterior end of first sternite to posterior end of anal tubercle, 16; length of coxa of fourth leg 5·5, trochanter 4, femur 9·5, patella 5; of same segments of third leg, 4·5, 3, 6, 3.

(*To be continued in our next Number.*)

III.—The occurrence of *Marsupites* in Flints on the Haldon Hills.

By A. J. Jukes-Browne, B.A., F.G.S.

WHILE examining recently a collection of specimens from the flint-gravel of the Haldon Hills in the Museum of the Torquay Natural History Society, I discovered among them four containing casts of plates of *Marsupites testudinarius*. Moreover, in reply to enquiries, Professor Clayden, of Exeter, informs me that the Albert Memorial Museum there possesses five such plates, and that one was found by Mr. F. J. Collins, of Exeter, about three years ago, so that the fossil appears to be not uncommon in the Haldon flints, and consequently it seems worth while putting the fact of its occurrence on record, with some of the inferences that may be drawn from it.

The casts are in pale grey flint, and it is somewhat remarkable that they show a strongly marked arrangement of ridges corresponding with those on the more ornate varieties of *M. testudinarius*. As the inner surface of all plates of *Marsupites* is smooth, I conclude that the plates embedded in flint were partially silicified, but even then it is not easy to understand the persistence of the ornament, unless this is structural and not merely an external ribbing.

The coarse gravel which caps the Haldon Hills is now believed to be of Eocene age, and Mr. C. Reid has shown that the travel of the stones composing these Bagshot gravels has been from west to east. The flints, therefore, may be accepted as having been derived from masses of Chalk, which then existed at a higher level than the plateau which now forms the summit of Great Haldon.

The existence of *Marsupites* in the Haldon flints is interesting, because it testifies to the former extension of that zone of the Chalk which alone yields this peculiar genus of Crinoidea. Dr. A. W. Rowe has shown that the zone of *Marsupites* in the South of England always consists of two bands or sub-zones, the lower characterized by *Uintacrinus* and the upper by *Marsupites*, and further, that plates of the latter genus very rarely occur in the lower band, being almost restricted to the upper band.

No Chalk now exists on Haldon, and the nearest outlier of Upper Chalk is at Beer Head, a distance of about 18 miles, while the nearest outcrop of the zone of *Marsupites* is a little west of Dorchester, about 48 miles from the Haldon Hills. The highest zone now remaining in Devonshire is that of *Micraster cortestudinarium* (near Beer), but the fossils found in the overlying flint-gravel testify to the former presence of the zone of *M. coranguinum*, and it has always been tacitly assumed that the higher zones of the Chalk were also formed over Devon and other western counties. We have now positive evidence of the western extension of the zone of *Marsupites*, but at present there is no actual evidence of still higher zones.

So far as I can ascertain, no remains of Belemnites have been found in the Haldon flints. Professor Clayden has kindly made enquiries for me at Exeter, and has searched through the collection

in the Albert Museum, but has not found any trace of Belemnites or of fossils characteristic of the zones of *Actinocamax quadratus* or *Belemnitella mucronata*. Of course this is negative evidence, but where *Belemnitella* is common in Chalk, as near Norwich, casts of its alveolar cavity are common in the flint-gravels, and one would expect the remains of this fossil to occur in the Haldon gravel if the zone of *Bel. mucronata* had been under erosion in Devonshire during the time of the Bagshot Beds. It should, however, be remembered that even if no fossils belonging to higher zones than that of *Marsupites* should ever be found on Haldon, their absence will not mean more than the absence of such zones within the area at the time when the Bagshot Beds were formed. It will not prove that the higher zones never extended into Devonshire, but simply that they were destroyed during the upheaval of the Chalk and before the formation of the Bagshot Beds.

The occurrence of the plates of *Marsupites* does, however, enable us to form an estimate of the total thickness of Chalk which may have existed in the neighbourhood of what are now the Haldon Hills when the Bagshot gravels were being accumulated. The Lower Chalk would be represented by only a few feet of calcareous sandstone, as on the Devon coast, and may consequently be neglected; the Middle Chalk is about 100 feet thick at Beer, and the mean thickness of the zone of *Holaster planus* in Devon is about 40 feet. To get an estimate of the thickness of the zones of *Micraster cortestudinarium* and *M. coranguinum* we must go to Dorset, where the mean of several measurements gives 80 feet for the former and 200 feet for the latter.[1] Finally, the thickness of the zone of *Marsupites* was found to be 111 feet near White Nothe, and *Marsupites* are only found in the upper 30 feet; if this depth was maintained to the westward, the total thickness of Chalk under erosion in Devonshire would be as follows:—

	feet.
Zone of *Marsupites testudinarius*	111
,, *Micraster coranguinum*	200
,, *Micr. cortestudinarium*	80
,, *Holaster planus*	40
Middle Chalk	100

We may therefore safely assume that the Haldon gravels represent the riddlings of about 500 feet of Chalk.

IV.—On a Cause of River Curves.

By C. Callaway, D.Sc., F.G.S.

In recent work on the laws of river-dynamics an important part has been taken by members of the Cotteswold Naturalists' Field Club. Dr. T. S. Ellis,[2] in 1882, announced the suggestive fact that the course of all the eastern tributaries of the Severn between

[1] See Dr. A. W. Rowe on "The Zones of the White Chalk of Dorset," in Proc. Geol. Assoc., 1901, vol. xvii, p. 11.

[2] "On some Features in the Formation of the Severn Valley." Read before the School of Science Philosophical Society, Gloucester. The geological world may perhaps be excused for overlooking the publications of this Society.

Berkeley and Tewkesbury was directed obliquely *up* the valley, a discovery which furnished the key to the relative ages of the Severn and the Thames.

Mr. S. S. Buckman also has worked with success in the same field, his ingenious paper in the GEOLOGICAL MAGAZINE[1] for August being only one of several contributions on river development. Some important observations on the curves of rivers have also been made by Dr. Ellis.[2] He remarks that all the affluents on both sides of the Severn in the Gloucester area come in on the *convex side* of the curves, and he notices that in all the windings of the Wye known to him, "where the river describes a great curve round a plain, one or more tributaries flow in at the convexity." Dr. Ellis considers that this effect is due to the tendency of the tributaries "to break away their banks on the lower side, at their confluence with the main stream, and to join together." This explanation I am unable to accept; but Dr. Ellis has hit upon a truth, and it has suggested to me the investigation of an interesting problem.

I have examined large numbers of Ordnance maps on the one-inch scale. They are from Western England, North, South, and Central Wales, the Lake District, the Highlands of Scotland, and many parts of Ireland. The result of this inquiry was the induction that in the vast majority of cases, probably nine out of ten, the affluents of the rivers enter on the convex side of the curves. This was true, not only of the main streams, but of the tributaries of the tributaries. I will give a few examples. The Severn between Shrewsbury and its junction with the Fyrnwy is about twelve miles in length as the crow flies, but probably nearly thirty miles in its actual course. Nineteen affluents are indicated on the one-inch map. Of these fifteen come in on the convex, two just above the convex, and two on the straight, but these are just opposite each other. Shrewsbury and Ironbridge are about thirteen miles from each other. The river makes numerous bends, generally in alluvium. Ten tributaries enter on the convex, two just above the convex, three on the concave, and two opposite each other, one on the convex, the other on the concave. Take the river Lug for a dozen miles below Leominster. About eight affluents enter on the convex, one comes in on the concave, and two enter opposite to each other, the *larger* stream on the convex side. Between Monmouth and Ross, a distance of nine miles as the crow flies, there are about a dozen flexures, with ten tributaries entering on the convex or just above it, and two on the concave, the concavities in the last two cases being subordinate to large convexities. The number of curves between Ross and Hereford (11 miles) is also very numerous, and *all* the fifteen affluents come in on the convex, or a little above it.

Turning to foreign countries, we discover the operation of the same law. For example, most of the tributaries of the Missouri enter on the convex side of the curves. Taking them from north to south, we notice that the rule is followed by the Big Sioux, the Kansas, the Mississippi, the Ohio, and many others, while I can find

[1] p. 366. [2] Loc. cit.

very few which come in on the concave. The same principle is seen to obtain in the Ganges, the Indus, the Po, the Danube, and every other great river system which I have examined. It is needless for me to multiply examples, as my statements can be easily tested by the inspection of reliable maps.

The coincidences I have pointed out cannot be accidental. They clearly indicate the operation of some law. They strongly suggest that the divergence of rivers in the direction of their affluents is due to the affluents themselves. How the divergence is produced I will now attempt to explain.

Let us suppose that a river is running straight forward, and a tributary comes in on one side at right angles. After heavy rains the affluent will bring down sediment, and will discharge it, or a part of it, into the main stream. Under ordinary conditions, a large proportion of this sediment will be carried obliquely down the river, and deposited on the opposite side, according to the law of the parallelogram of forces. Let A B (Fig. 1) be the river, and C D its affluent. Then let the line *ab* represent the force of the river in magnitude and direction, and *cd* the force of the affluent. Then a large part of the sediment brought in by C D will be carried along the line *cb*, and deposited at *b*. Some of the detritus may sink to the bottom before *b* is reached, and some of it will probably be carried down below *b*; but there must be considerable deposit at *b*, for at that point the lateral force *cd* will be balanced by the reaction of the bank, and the carrying power of the current will be reduced. Of course, the finer sediment will be transported further than the coarser particles, and *b* will be a short line rather than a point. The growth of this new land at *b* will cause a deflection of the current, which will impinge upon the opposite bank lower down, and will begin to excavate. A series of curves will thus be initiated according to principles which need no explanation in these pages.

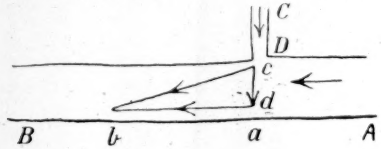

Fig. 1.—Affluent (C D) entering river (A B), and depositing sediment at *b*.

Not only will the deposit at *b* grow by additions from the affluent CD; it will form a barrier projecting into the stream, and in the slack water above it sediment from the main river will be thrown down.

According to the explanation I have just given, the normal position of the affluent should be a little *above* the convex curve, and this is very frequently found to be the case. But the new sediment thrown down above the projection formed at *b* will cause the projection to grow up-stream, so that in time it will reach as high as the tributary, or even higher; and the latter will enter, not

above the convexity, but in some part of it. Fig. 2 will illustrate this point. The affluent CD enters the river AB above the convexity. But the delta-like mass of land E has grown up-stream, and the broken lines represent the new course of the river, with the affluent entering it at D′.

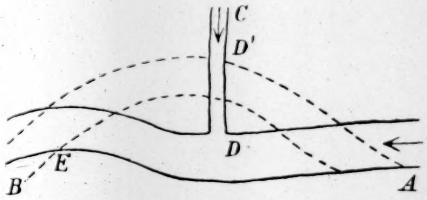

Fig. 2.—Growth up-stream of delta (E) formed by affluent C D, subsequently C D′.

The principles I have expounded are quite consistent with the occasional entrance of a tributary on the concavity of a curve. This may occur in several ways.

1. An affluent may originally have entered the river on the convex. Then a change may take place in the main stream by increase or decrease of slope or volume, so that a new set of curvatures may be produced, the causes in operation being powerful enough to overpower the effect of the affluent. Thus a concavity may take the place of a convexity.

2. An affluent may enter on the concave owing to its excessively swift motion. This appears to be the case in the valley of the Rhone near Sion. According to Lord Avebury,[1] the Borgne falls into the Rhone at this place with such velocity as to drive it to the opposite side of the valley, the affluent entering the Rhone on the concave across an alluvial flat. It would seem that the entry of the tributary was originally so swift that it struck the further bank and rebounded, so as to deposit its sediment *on its own side.* The growth of this delta would gradually force the Rhone to the opposite side of the valley.

3. Two affluents may enter a river opposite to each other. The one that entered with the greater velocity (up to a certain point) would be likely to come in on the convex, for it would have greater power to convey its sediment to the opposite bank, and thus to draw the river to its own side. The smaller tributary would of course come in on the concavity.

4. The entry of an affluent on the concave may be due to the deposit of sediment at the junction of the two streams. An interesting example of this occurs on the Severn, about 6 miles south-east of Shrewsbury. It is shown in Fig. 3. Cound Brook enters on the concave at A. The last mile of the course of the brook is through an alluvial flat. Now it appears highly probable that at one time the river curved round into this bay, as suggested by the broken lines; otherwise its excavation is not

[1] "Scenery of England," p. 319, fig. 133.

easily explained, since the affluent would not degrade, but deposit. If this supposition is correct, the brook must then have entered on the convex at B. Its current would thus meet the current of the river almost directly, the two opposing forces would cause partial equilibrium, and detritus would be thrown down. As this new land grew, it would push the Severn further and further towards its present position. At a late stage of the process, it would seem as if the opposing currents created the tongue of land CA, so that the brook is forced to fall into the river on the concave at A.

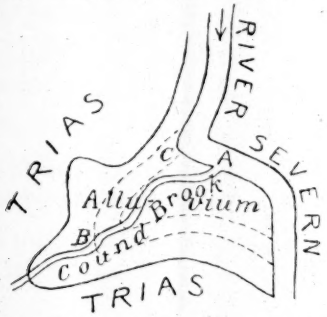

FIG. 3.—Junction of Cound Brook with River Severn, showing change of infall on the convex to infall on the concave.

It is evident that the effects produced at the confluence of a river and its tributary depend on very varied conditions. The most important of these are the angle between them, and their relative magnitude and velocity. It is conceivable, for example, that an affluent, even one of relatively large size, may fall into a river without giving rise to marked curvature. If the main river is flowing swiftly, and the affluent is sluggish, the latter will have too little momentum to materially disturb the momentum of the former. Part of the sediment carried by the tributary would be thrown down at its junction with the river, and the portion which entered the latter would be swept down for a considerable distance.

On the other hand, if the conditions are favourable to deposit on the opposite bank, an affluent will cause marked divergence of the main stream. This is well seen at the confluence of the Severn with the Tern, of the Wye with the Lug, of the Avon with the Arrow below Stratford, and of the Trent with the Tame. Besides the new deposits on the opposite bank, affluents may also create islands in the main river, as in the Severn at its junction with the Tern, and in the Teme at the infall of the Laughern Brook. Alney Island, at Gloucester, probably originated in this way. It is about two miles in length, with an arm of the Severn running down each side of it. The western arm receives the river Leadon and a smaller stream, while the Hatherly Brook and another affluent enter the eastern branch. The currents of these tributaries coming in on opposites may well have caused a certain amount of dead water, and consequent deposit of sediment. A small island formed in this way

would grow by arresting the current of the Severn, whether the tide were descending or ascending.

I need hardly point out that my theory does not require an affluent at every convex curve. If the current of a river is once deflected, flexures may be produced indefinitely, in the manner described in textbooks. Nor does my explanation apply to tidal sections of rivers, since the alternations of current motion would obviously produce effects differing widely from those I have described.

The textbooks tell us that a series of river curves may be initiated by an obstruction, such as a tree or a fall of rock, producing a deflection of the current to the opposite bank. Or the curves may be caused by differential resistance in the materials through which the river is flowing. I have no objection to these explanations. They probably apply in some cases, but I think they are much less important than the theory I have proposed. They have been imagined rather than proved.

How far the explanation I have offered will apply to rivers which are now running in solid rock is a question into which I do not here propose to enter.

V.—Some Remarks on the Atlantis Problem.

By R. F. Scharff, Ph.D., B.Sc., F.Z.S.[1]

SINCE the dawn of early history the question of the existence of a continent beyond the "pillars of Hercules" has occupied the mind of man. Our very earliest records of this mythical land were derived from a narrative which has been handed down to us by Plato. According to it, Solon is said to have visited Sais in Egypt, and there to have heard from priests of the ancient "Empire of Atlantis" and of its overthrow by a convulsion of Nature. This Atlantis was then spoken of as a vast land lying beyond what we now call the Straits of Gibraltar, and it is supposed to have been inhabited by a mighty race of people. Plato's story has called forth quite a flood of literature, not only in ancient times; even within the last score of years many pamphlets and books have been published dealing with this attractive problem. Some authors have sought to discredit the veracity of Plato's assertions, while several, and among them Humboldt and Sir Daniel Wilson, were of opinion that the tale rests on some historic basis. Others, again, have utilised the original story and connected it with their own ideas of a land-bridge stretching right across the Atlantic from Europe to America.

The Atlantis problem, however, was only raised to scientific importance when modern research revealed the fact that the living as well as the extinct flora and fauna of Europe have quite a number of types in common with North America. Unger was the first to put forward the view, from a purely scientific reasoning, that the Atlantic Islands, that is to say, the Azores, Madeira, and Canary Islands, formed part of a land-connection which stretched right

[1] A paper read before the British Association in Section D (Zoology), Belfast, 1902.

across the Atlantic and still preserved some of the plants which invaded our Continent from the New World. Heer hailed this hypothesis with delight, while Andrew Murray adopted it in a somewhat modified form. Edward Forbes also occupied his fertile mind with the problem, but could not convince himself that the vast land which had evidently occupied a portion of the Atlantic had any connection with America. Wollaston, too, who had a most intimate knowledge of the Atlantic Islands, strongly supported the view that their fauna reached them across dry land.

Imbued, however, with the idea of the permanence of the great ocean basins, Wallace vigorously attacked one and all of these theories, and contended that there was not only no connection between Europe and America across the Atlantic, but that the fauna of the Atlantic Islands was derived from the adjoining continents of Europe and Africa by winds and marine currents. The weight of the arguments brought forward by Wallace silenced all critics for a time, and the influence of his views is traceable in most of the more recent writings on the subject. But since some leading geologists have expressed themselves against the theory of the permanence of the great ocean basins, the older views of a possible land-connection between Europe and the Atlantic Islands, and also between Europe and America, are again discussed. I have therefore collected together a number of facts in the distribution of animals which had not hitherto been utilised, in order to make a renewed attempt from a zoological point of view to solve the Atlantis problem.

The results of my investigations tend to show that Madeira and the Azores are the remains of an ancient tertiary area of land which was joined to Europe, and that it probably became disconnected in Miocene times. Since then this land once more became united with our Continent, and may not have been finally severed until the Pleistocene period. As regards the question of a land-bridge across the Atlantic, many reasons can be given in favour of such a theory. It must, however, have occupied a position farther south than the land just alluded to. Uniting North Africa with Brazil and Guiana in early tertiary times, it probably subsided during the Miocene period, leaving only a few isolated peaks as islands in the midst of the vast ocean which has since replaced it.

VI.—On the Geological Structure of Ireland.

By Professor Grenville A. J. Cole, F.G.S.[1]

In this illustrated lecture, the more prominent phases of the geological history of Ireland were pointed out, mainly as an explanation of the existing scenic features of the country. Probably very little remains in Ireland of the old Huronian continent, unless portions of it have appeared again in the cores of Caledonian folds. The stratified, but metamorphosed, Dalradians of the west may be

[1] A paper read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

Cambrian, or older; and gneiss is included in the granite of eastern Tyrone, the latter being probably of Caledonian age. The gneiss of the ancient moorland between Omagh and Cookstown is, moreover, very possibly pre-Cambrian. The Silurian sea must have covered all the Irish area; and the subsequent Caledonian folding, with its axes running north-east and south-west, marked out the first distinct lines of the existing country. The arches became filled with molten rock as they rose, and denudation has again and again exposed in them a core of granite. To this folding we owe the guiding lines of Donegal, Sligo, and Mayo; the axis of Newry, which reaches from the sea—and, indeed, from Scotland—down into the midland counties; and, above all, the long mass of the Leinster Chain, the most important feature of south-eastern Ireland. The granites weather into round-backed moorlands; the schistose foothills give rise to picturesque ridges and ravines upon their flanks. In the Dublin area, between the foothills and the sea, quartzites and slates, usually regarded as Cambrian, have added the prominent features of Howth, Bray Head, and the two Sugarloaves, to an already diversified landscape.

The Old Red Sandstone lakes spread across the hollows of the Caledonian continent, to be succeeded by the inflow of the Carboniferous sea. The Lower Carboniferous beach-deposits are now found on the summits of west Irish mountains, and very little of the country can have escaped submergence. The Hercynian folding produced the second series of structural lines, assisted by the varying resistance of the Old Red Sandstone and the Carboniferous Limestone to denudation. The east-and-west anticlinal ridges, from the Atlantic to the Irish Channel, with intervening valleys, where the limestone is protected in the synclinals, repeat on a bold scale the structure of South Wales and Belgium. The folds swung round in the neighbourhood of the pre-existing Leinster Chain; and the axis of the Kilkenny Coalfield, where the Coal-measures remain on a high synclinal, runs north-east and south-west, like its neighbour on the east. The great limestone plain itself is probably to be looked on as a vast shallow synclinal of the same epoch, into which, in later periods, the Caledonian and Hercynian ridges poured down their detritus.

Marine Permian beds occur near Stewartstown, south-west of Lough Neagh, and also in the north of County Down. The terrestrial conditions of the British Trias were continued into the Irish area, but the remaining beds of this period all lie north of Dublin, and mostly owe their preservation to the capping of Cainozoic basalt. The Rhætic sea penetrated as far west as the Caledonian hills of Londonderry, and marine conditions continued during early Liassic times. An uplift then probably occurred, and the sea did not return till the middle of the Cretaceous period. The 'White Limestone,' which forms so distinctive a feature of the Antrim coast, represents the English Chalk.

The great feature of the north is, however, due to volcanic eruptions of Eocene age. Owing to the immense outpouring of

basalt across the uplifted Cretacous and earlier strata, the counties of Antrim and Londonderry include high igneous plateaux, cut by deep valleys in which the underlying rocks are seen. The landscapes close around Belfast reveal the structure of the country in perfection. In the west of Ireland, dykes of basalt, running characteristically north-west and south-east, are so frequent as to show that the plateaux once prevailed from Down to the Atlantic coast. Sporadic eruptions occurred even in the Galway area, and basalt fragments prevail on the sea-floor between Ireland and Rockall. The granite of the Mourne Mountains was intruded in the same period of unrest, and the pinnacles and rocky walls of the group are a sign of youth when compared with the older granite areas in Ireland.

The existing surface of northern Ireland was determined by the falling-in and dislocation of the volcanic country that once spread northward to the Faröe Isles. Lough Neagh thus lies in a shallow basin formed during this epoch of subsidence and decay. The long sea-inlets of the north and west, including Belfast Lough and the 'rias' and 'fjords' of Connemara and Kerry, originated about the same time; but Ireland, now cut off from the lost continent on the north-west, became joined on to the growing continent of Cainozoic Europe. The spread of ice in glacial times is marked by numerous hills of gravel and eskers, especially in the central plain, where they form green ridges rising from the bogland and the prairie. The oscillations of level between the glacial epoch and the present day finally left Ireland cut off from Scotland, Wales, and England, with which her fundamental geological structure so obviously connects her. It is interesting to note that the most prominent features of her landscapes at the present day depend on structures impressed upon the area far back in Palæozoic times.

NOTICES OF MEMOIRS, ETC.

I.—British Association for the Advancement of Science. Belfast, September 11th, 1902.

Address to the Geological Section, by Lieut.-General Chas. Alexander McMahon, F.R.S., F.G.S., President of the Section.

Rock Metamorphism.

After some prefatory remarks, the President said a brief description of a granite in the Satlej Valley of the Himalayas will, I think, introduce us by a short cut to the question of "contact metamorphism," an important branch of the subject under consideration. The granite I allude to is an intruder in the normal gneissose-granite of the Himalayas, and cuts through it at right angles to its foliation. The intruder, which is some yards wide, did not rise through a simple crack or fissure, for its passage upwards was interrupted by a sheet of dark intrusive diorite, older than itself, which ran, roughly speaking, parallel to the foliation of the gneissose-granite. This sheet of diorite offered considerable

resistance to the rising granite. The granite zigzagged backwards and forwards across the diorite and ran along its edges for fifty yards or more, converting it into a mica trap. It then tore itself away and continued its upward course. The granite I am describing was in a molten or fluid condition at the time of its eruption, as I hope to show in my subsequent remarks.

I may pause here, however, to consider in passing what was the probable temperature reached by a granite such as that above described. The question is one of very great difficulty, as we know so little about the plutonic conditions of igneous rocks, and can only arrive at an answer to our question by indirect evidence. The melting-point of quartz ranges from 1425° to 1450° C., but the fusion-point of granite need not necessarily be as high as this, inasmuch as the presence of water at high temperature materially lowers the melting or solution point. The fusion-point of the other constituents of granite may here be mentioned: that of orthoclase ranges from 1164° to 1168°; microcline, 1169°; albite, 1172°; augite and hornblende, 1188° to 1200°; apatite, 1221°. Zircon, which is commonly found in granites, and is one of the first minerals to separate out of the magma, is shown by Ralph Cusack to have probably a melting-point of 1760°; whilst topaz, a not uncommon mineral in granite, is infusible up to the melting-point of platinum, namely, 1770° C.

If we consider, therefore, the melting-points of the mineral constituents of granite, we can hardly avoid the conclusion that for the magma to have attained perfect fluidity it must have reached a temperature of at least 1200° C. Vernadsky has shown that kyanite is transformed into sillimanite, a well-known product of contact-metamorphism, at a temperature of 1320° to 1380°. If rocks in contact with granitic masses have been raised to this temperature, it follows that the granite itself must have been still more heated. Vernadsky's observations have been relied on by Mr. George Barrow in his well-known paper "On an Intrusion of Muscovite-biotite Gneiss" in the S.E. Highlands of Scotland to account for the presence of sillimanite in the inner zone of metamorphism between the kyanite schists and the granite, and he considered that the temperature attained by the "central masses of the Highland rocks" was probably higher than the figures indicated by Vernadsky.

Bearing all these considerations in mind, including the influence of water and alkali in reducing, and of pressure in raising, the melting-point, I think we may safely infer that granites, such as the Himalayan granite alluded to above, must have been raised at plutonic depth to a temperature midway between red and white heat, that is to say, to at least 1200° C.

To return to the granite of the Satlej Valley under consideration, I wish to draw attention to its condition just before crystallisation commenced. A study of the mineral beryl will, it seems to me, throw light on this point. Beryl is an important accessory mineral of the granite under description. It is clearly an original mineral,

and it is material to note that it was the first mineral to crystallise out of the magma of the Satlej granite. This is shown by several circumstances.

In the first place, the beryl preserved its perfect crystallographic shape, showing that its molecules during the entire period of crystallisation possessed comparative freedom of motion, and were not interfered with or molested by other solid minerals. In the second place, all the essential minerals of the granite when they subsequently crystallised out of the magma were deposited on the crystals of beryl. I have specimens of the granite showing crystals of beryl enclosed in felspar, in muscovite, and in quartz.

The beryl, therefore, having been the first mineral to crystallise, the examination of thin slices of it under the microscope ought to give us a clue to the condition of the magma at the time the beryl was formed. I have made such an examination, and I find that the beryl is crowded with liquid and gas cavities, the former containing movable bubbles and deposited crystals as well as water. The bubbles are of substantial size relative to the area of the cavities, showing that the water suffered considerable contraction after it was sealed up in the beryl.

Scrope long ago suggested that the fluidity of lavas below the melting-point was due chiefly to the water they contained, and attributed the liquidity of granite to the same cause. Scrope, however, in ascribing the mobility of an igneous rock to the presence of water, seems to have had regard principally or wholly to its mechanical action in furnishing an elastic medium in the interstices between the crystals or grains of the rock. He observes that a lava consists "of more or less granular or crystalline matter, containing minute quantities of either red-hot water, or steam in a state of extreme condensation, and consequent tension, disseminated interstitially among the crystals or granules, so as to communicate a certain mobility to them, and an imperfect liquidity to the compound itself," and he quotes Scheerer and Delesse, both of whom assert that water exists in mechanical combination with all crystalline rocks, "its minute molecules being intercalated between the crystals."

Nowadays one would attribute the liquidity of an igneous rock not so much to the mechanical action of the water present in it as to the combination of the water with the mineral contents of the lava, producing a state of solution. Sorby's investigations supported Scrope's observations, for he proved that the liquid contained in the inclusions in granite is water, and showed that it was caught up during the formation of the crystals, "and was not introduced subsequent to the consolidation of the rock." The water now contained in cavities in the beryl was probably held in solution by the constituents of that mineral at the time of its formation, and as it cooled down the water separated from the substance of the beryl and formed the cavities in which we now find it imprisoned. If this be so, it follows that when the beryl crystallised out of the magma, the latter was in a fluid condition, and held a considerable

amount of heated water in solution. The temperature of the magma must have been above that of red heat, and the potential energy of the water held in a fluid state by pressure must have been great. When, therefore, in the course of the earth movements which accompany or in some cases are caused by the intrusion of eruptive igneous masses, pressure was temporarily relieved by the rupture and faulting of rocks, the superheated water contained in the magma would be ready to flash into steam with almost explosive violence. It must also be borne in mind that water under great pressure, at or above a red heat, has a powerfully solvent action on most minerals, even on so refractory a mineral as quartz. When, therefore, granite in the molten and fluid condition of the Satlej granite was erupted along a line of faulting, fissure, or weakness, the superheated water or steam, bearing with it much mineral matter in solution, must have acted with great chemical energy on the rocks into which it was intruded.

I have spoken of water carrying mineral matter in solution, and of a magma carrying water in solution. These two conditions may rapidly succeed each other under varying conditions of temperature and pressure. To use the words of Van Hise, "under sufficient pressure and at a high temperature there are all gradations between heated waters containing mineral material in solution and a magma containing water in solution." The condition of the beryl crystals, crowded as they are with liquid cavities, shows how high a proportion of superheated water was contained in the fluid granite magma at the time of their formation.

Sorby estimated that the fluid cavities in the quartz of granites sometimes amount to more than ten thousand millions to the cubic inch. As quartz, however, is usually the last mineral of a granite to consolidate, it may be thought that the water contained in it is a residuum left by the felspar and muscovite on their separation from the magma; but the case of the beryl above quoted shows clearly that the amount of water diffused through the magma before the mica, felspar, and quartz began to consolidate must have been very considerable. The amount of water held in solution by a granite, during the time of its aqueo-igneous fusion, cannot be estimated by the amount of water given in the analysis of consolidated and dried hand-specimens of that rock. A considerable proportion of this liquid must necessarily have been lost during the gradual cooling of the rock, and in the course of its intrusion into neighbouring sedimentary strata as sheets, dykes, and veins. Sorby, as the result of other lines of investigation, came to the conclusion that the amount of water present in granite, though limited, is considerable.

We must now turn for a few minutes to consider the important question of the porosity of minerals, and their permeability by heated water and gas at high pressure. The fact that solid substances are built up of molecules having interstitial spaces between them hardly needs demonstration nowadays. But have we all quite realised that the molecules of rock-forming minerals and crystals are not inert particles of matter, but that they vibrate or revolve or are

endowed with other orderly movement that may be likened to the motion of the planets round the sun? Far, far away in space the solar system would, to an eye formed like our own, in all probability present a nebulous appearance, because the eye would not be able to see the individual members of our system. So, too, the molecules of which crystals are built up may have their appropriate motions, but we cannot see them with the eyes of sense because the molecules are beyond the highest powers of the microscope. We can, however, I think, perceive them with the eye of the scientific imagination; and the hypothesis that the molecules of minerals are separated from each other by intermolecular spaces, and have their modes of motion, seems essential to the comprehension of rock metamorphism.

The important experiments of Sir W. Roberts-Austen on the diffusion of gold in pure lead throw considerable light on this subject. Disks of solid gold were held against the bases of cylinders of lead by clamps, and were kept in an upright position at the ordinary temperature for four years. At the end of this time it was found that the gold had diffused upwards in the solid lead, for a distance of 7·65 mm., in sufficient quantity to be detected by the ordinary methods adopted by assayers. Traces of gold were found still higher. When a column of molten lead, 16 cm. high, was placed above solid gold and kept at a mean temperature of 492° C., that is to say, at 166° above the melting-point of lead, but 569·7° below that of gold, the gold diffused in considerable amount, to the top of the lead column, in a single day.

Sir W. Roberts-Austen's experiments, above alluded to, demonstrate that even such metals as gold, whose melting-point is as high as 1061·7° C., exhibit a measurable amount of kinetic energy at the ordinary temperature and pressure. Great results may no doubt be brought about at ordinary temperatures and pressures, when time, as in the laboratory of nature, is practically unlimited; nevertheless, the importance of high temperature and high pressure, in operations connected with metamorphism, can hardly be overrated. Not only does a rise in temperature increase the energy of the chemical actions and reactions which produce the mineralogical changes embraced by the term metamorphism, but it increases the porosity of minerals and facilitates the passage of liquids and gases through their pores. The cohesion of molecules is lessened, the amplitudes of their vibrations, rotatory or other movements, are increased, and a passage is opened for the advance of chemical materials into the heart of the crystal.

Increase of temperature thus not only throws open the doors of the mineral fortress attacked, but gives enhanced energy to the invaders. The fact that the mineral components of a rock are, under conditions of heat and pressure practically porous to heated water, laden with chemical reagents in solution, is frequently brought home to the mind of the petrologist in a very tangible way. We sometimes observe, for instance, that metamorphic changes begin at the heart of a crystal, and leave the peripheral portions

of it fresh and unaltered. In such cases the chemical agents of change have evidently passed freely through the outer parts of the crystal, and have by preference selected its internal parts for attack.

In order to explain clearly how this remarkable result takes place, in the cases referred to, it will be necessary to diverge for a few minutes to consider another branch of our subject. It is difficult, if not impossible, to lay down any hard-and-fast rule of universal application, because the conditions under which igneous rocks crystallise vary with temperature, pressure, the relative proportion of constituents, and other local causes, and these variations in the conditions may materially affect the results; but I think the rule that minerals crystallise out of a molten magma in the order of their basicity is of very frequent if not of absolutely general application. This rule also governs the growth of individual crystals, especially those that exhibit what is known as zonal structure. Take, for instance, the felspars of an igneous rock. A gradual passage may frequently be traced by the petrologist from one species of felspar at the heart of a crystal to another distinct species at its periphery. Sometimes a crystal is made up of more than two species, which shade more or less gradually into each other. In accordance with the rule laid down above, the more basic species formed first; then, as the percentage of the bases left in the magma gradually decreased, owing to the first formed crystals having taken a lion's share of the available bases, the felspars that formed later became gradually more and more acid in composition. Thus a large felspar of slow and gradual growth may be composed of several zones, each zone being successively less basic and more acid than that upon which it crystallised, each successive zone thus possessing slightly different physical properties from the one that formed before it. These statements are capable of proof. When sections of felspars, such as occur in thin slices of igneous rock, are examined under the microscope in polarised light, petrologists can distinguish one species from the other—when the direction in which the sections were cut is approximately known—by measuring the angles at which they extinguish from the twinning or the pinacoidal plane.

This is not mere theory. Each species of felspar has its own angle of extinction and its own index of refraction. The determination of these two factors enables a petrologist to prove optically the change in composition; or, in other words, the change in species which has taken place in the successive zones during the gradual growth of a large zonal felspar.

Another general rule must now be mentioned. I think it may safely be asserted as a broad rule, that the different species of felspars are attackable by the chemical reagents which make themselves felt in metamorphic action, in the order of their basicity; that is to say, the more basic felspars are more easily attacked than the acid ones. When we bear in mind the facts stated above, we shall, I think, be able to see clearly how it is that the peripheral portions of large felspars in igneous rocks sometimes escape alteration, whilst the cores of these crystals are converted into secondary minerals, such as

chlorite, silvery mica, zoisite, epidote, kaolin, steatite, saussurite, calcite, and scapolite. The chemical reagents flowing in solution through the pores of the felspars, pass by the more acid and refractory species, and devote their energies to the more susceptible basic species entombed at the heart of the zonal crystals.

The point I wish to enforce most strongly is that the phenomenon above described, namely, the formation of secondary metamorphic minerals in the interior of a crystal, combined with the comparative immunity to change of the external portions, shows that the agents which brought about chemical changes at the core of the crystal flowed freely through its unaltered peripheral portions.

But some may ask whether the chemical agents referred to may not have gained access to the heart of a crystal by a crack. I answer that a crack is a coarse and tangible object that looms large under the microscope. A crack in a mineral liable to metamorphic action, through which chemical reagents have flowed, could not escape detection. The finest crack through a homogeneous mineral, such as, for instance, an olivine, can be readily seen, not only by the small canal worn by the corrosive action of the chemical agents that flowed through it, but by the alteration set up in the mineral along the whole course of the canal.

I have a thin slice from a beautifully fresh olivine contained in one of the lavas of Vesuvius collected by myself. A volcanic explosion or other cause, operating after the crystallisation of the olivine, produced a very fine crack in the mineral through which water, charged with chemical reagents, subsequently flowed. The crack, though of microscopic width, is filled with serpentine, and on both margins fibrous serpentine has been formed at the expense of the parent olivine, and constitutes a fibrous band on both sides of the crack throughout its entire length, the direction of the fibres being at right angles to the crack. The rest of the olivine is of virgin purity and polarises in the most brilliant colours, contrasting strongly with the serpentine.

In this case it is clear that the chemical reagents, though free to flow along the crack, had commenced to extend beyond its walls, encouraged thereto by the porosity of the olivine itself. But how different is this case from those in which the entrance of the chemical agents had not been facilitated by a crack. In the case above described, the chemical changes set up were limited to the borders of the crack, and even had they gradually extended in the course of time to the whole of the olivine, the original canal by which the chemical reagents had gained access to the crystal would have remained to tell its tale, and exhibit along its course the banks of iron oxide thrown up by the chemical navvies that had excavated it.

Cracks save time as roads and canals do, but they leave behind them evidence of their former existence. In order to understand fully how rocks and minerals are so completely open to the attacks of chemical reagents, which penetrate to and produce chemical and mineralogical changes at the very hearts of minerals, we must fully realise how completely porous rocks and minerals are to the heated

liquids which carry these reagents with them in solution. Heat, as before stated, not only increases chemical energy, but destroys more or less completely the cohesion between molecules, and increases the amplitude of the vibrations, or other motions of the molecules, and consequently facilitates the entrance of liquids and gases into the pores of minerals, and their complete permeation by these powerful agents of change. Thus far we have been chiefly concerned with some of the principles underlying the branch of our subject embraced by the term contact-metamorphism, which implies operations conducted at considerable depths below the surface of the ground, under conditions of heat and pressure.

We must now consider very briefly changes produced at or near the surface by the agency of water, or, as Bischof in his well-known work termed it, metamorphism in the 'wet way.' No hard-and-fast line, however, can be drawn between the two classes of operations, as the one gradually shades by fine gradations into the other. At one end of the scale we have high pressure and high temperature, and a fluid igneous magma holding water in solution, above a red heat, and giving up heated water or vapour charged with salts to the rocks in contact with it. Passing to the other end of the scale through diminishing temperatures and pressures, we reach a condition in which the water circulating through the rocks at ordinary pressure and temperature is more abundant in amount, and holds acids and salts in solution, capable of setting up important chemical reactions in the rocks and minerals to which it gains access.

In the case of surface operations, moreover, the metamorphic agents—water, acids, salts—are being constantly renewed. Conditions differing as widely as the conditions at the extreme ends of our scale do not yield, however, precisely the same results. In both metamorphic change goes on with more or less briskness, but the products are different. Some minerals require great heat and great pressure for their production, and such minerals are never formed by any surface process of weathering. For instance, the temperature reached determines whether titanium dioxide crystallises as rutile, or in one of its other two forms, rutile requiring a temperature of over 1000° C., and being the only form of titanium dioxide 'stable at a high temperature.'

Temperature also seems to determine whether the silicate of alumina crystallises as andalusite, kyanite, or sillimanite, the two former being transformed into the latter, at a temperature of 1320° C. to 1380° C. On the other hand, some minerals require little heat for their formation, and are readily produced by metamorphic changes in the 'wet way.'

There seems to be some correspondence between the melting-point of minerals and their density; thus, in the case of eleven minerals produced by contact-metamorphism, whose average specific gravity ranges from 3·06 to 4·03, I find that their melting-point ranges from 954° to above 1770° C., high temperature and high pressure (a concomitant of plutonic conditions) appearing to be factors in the production of high specific gravity in minerals.

The genesis of individual species of minerals is a fascinating study, but the subject is too large to enter upon here.

Water gains access to rocks in several ways. It falls as rain; it rises from hidden depths; it leaks from the sea into horizontal beds or into strata dipping away from it; and it penetrates through faults and fissures. Rain in its descent takes up from the air oxygen, nitrogen, carbonic acid, and in some cases small amounts of nitric acid. It is thus in itself a powerful solvent and potent agent in producing chemical change. In its passage through the surface soil it dissolves humic and other organic acids, the products of vegetable decay, which add greatly to its solvent power and enable it to break up many silicates and to dissolve even silica. By the time the rain-water reaches the solid rocks below the surface soil, it has become a very active agent in producing chemical change in them. It is by such agents, persistently applied during long periods of time, that large areas of ultra-basic igneous rocks have been altered into serpentine.

Hot springs are a well-known instance of water rising in considerable quantity from plutonic depths. They are known to occur in the plains of India, and are especially abundant in the Himalayas. I visited two very interesting ones at Suni, in the bed of the Satlej River, west of Simla. The springs rise apparently under the very bed of the river, and come to the surface on both banks within a yard or two of the rushing water of the Satlej. When I visited the springs they had a temperature of 130° F., and contrasted strongly with the cold water of the river flowing past them, which had descended from high Himalayan glaciers and had a temperature of 49° F.

The native inhabitants of neighbouring villages told me that the hot springs always appear at the very edge of the river, whatever may be the height of its waters during drought or flood. This statement is probably true, for I think the springs well up from below through the walls of a fault that traverses the bed of the Satlej at a high angle to its course, and the springs thus come to the surface on both its banks.

The metamorphic influence of these springs on the rocks in this locality has been very powerful. The ancient volcanic rocks there exposed have, for some distance up the river, been altered by aqueous agents almost out of recognition. The original structural characters of these lavas have been almost completely broken down, and an amorphous substance substituted for the crystals and minerals of which they were originally composed.

This result shows that the crystals and minerals of these old lavas must, for all practical purposes, have been completely porous to the aqueous agents brought to bear on them.

The general transmutation of one mineral into another by the action of heated water holding mineral agents in solution, aided by heat and pressure, may take place in a variety of ways. Some of these processes are simple, but others are highly complex. Many are the results of a single operation, others of a series of changes,

some of which prepare the way for those that follow. In some cases the change may be brought about by the removal, in whole or in part, of one or more of the essential constituents of a mineral, whereby the relative proportions and mutual relations of those that remain are altered, as the following examples will show.

By loss of water limonite passes into hæmatite, and opal into crystalline quartz. Dyscrasite, by loss of antimony, passes into native silver, and pyroxene, by the removal of its lime and iron, is changed into talc. Simple oxidation or the absorption of oxygen by a mineral is responsible for another class of changes, as in the conversion of zinc blende into goslarite, and antimony into valentinite.

The loss of one or more of the ingredients, concurrently with the introduction of one or more new ones, causes many metamorphic changes, as in the conversion of marcasite into magnetite, of witherite into barite, and of azurite into malachite.

The well-known conversion of a peridotite into serpentine is a case in point. Here, part of the iron and magnesia is removed from the olivine, and water is introduced. A simple process like this, brought about by the percolation of surface waters through an igneous rock, is sufficient to transform considerable areas of rock masses into serpentine, as has been the case in parts of Cornwall.

Some metamorphic processes are more complex than those alluded to above, but Nature has unlimited time at her disposal, and is able to manufacture potent chemical reagents as her processes proceed. For instance, the sulphides of various metals of common occurrence in rocks, most of which, with the exception of those of the alkaline metals, are insoluble in water, by taking up oxygen pass into sulphates, most of which are soluble in that liquid at the ordinary temperature. These sulphates are readily carried away in solution, and become potent factors of change in rocks through which water charged with these salts flows. Again, carbon dioxide, so abundant in percolating water, decomposes minerals containing lime or alkali, and removes them as soluble carbonates to effect powerful chemical reactions elsewhere.

I must pass over the subjects of paramorphism and pseudomorphism, as the limited time at my disposal does not permit me to enter upon these subjects. In the above sketch I have entered upon a discussion of some of the leading principles that seem to me to underlie contact action and metamorphism in the wet way, because I venture to think that, if we really understand these two divisions of our inquiry, it will be unnecessary on the present occasion to enlarge on other branches of our subject.

Take, for instance, what is commonly called dynamic-metamorphism. The main factors in this kind of metamorphism are the folding, crumpling, crushing, and shearing of rocks by earth movements, especially during the upheaval of mountains. But these dynamic forces are potent factors in the development of heat. In the case, therefore, of dynamic-metamorphism, as in contact-metamorphism, pressure and heat are the main factors acting in

conjunction with the water shut up in or circulating through a rock. If we understand how these factors operate and produce the results we see in cases of contact-metamorphism, we shall not fail to understand their action in a case of dynamic-metamorphism.

These observations also apply to regional metamorphism; that is to say, to metamorphism produced in rocks at great depth, by being brought within the influence of the interior heat of the earth. The action of heat in increasing molecular motion and kinetic energy is well understood nowadays, and so long as we get heat it seems to me immaterial how heat is generated in rocks subject to metamorphic action.

In the above sketch I have intentionally omitted to enter into the details of chemical action that has brought about individual cases of metamorphic change. Volumes would be required to do justice to so complex a subject, and the details would, in an opening address, be out of place.

In conclusion, I have, I trust, shown how important a part water plays as an agent of metamorphism, not only at and near the surface of the earth, but at plutonic depths. We have seen that the molten granite of the Satlej Valley, which was given as an illustration of a fluid igneous magma, contained a considerable proportion of water held in solution at considerably above red heat, and that the fluidity of the magma was due to its presence. We also saw that the great heat to which the magma was raised increased the potential energy of the contained water; a relief of pressure then opened the way for the intrusion of the molten magma into neighbouring rocks. We also saw that this water was rendered by heat a powerful solvent, and that it carried with it into the adjoining rocks the mineral matter of the granite in solution. We also saw that heat increased the porosity of minerals, facilitated the passage of liquids laden with mineral matter through their pores, and increased the potency of chemical action.

II.—List of Titles of Papers read before the British Association for the Advancement of Science, Belfast, Sept. 10–17, 1902, in the Geological and other Sections bearing upon Geology.

Section A (Mathematical and Physical Science).

Dr. Isaac Roberts, F.R.S.—Illustrations obtained by Photography of the Evolution of Stellar Systems.

Major S. G. Burrard, R.E.—On the Figure of the Earth.

J. Milne, F.R.S.—Observations on Earthquakes.

Report of the Seismological Committee.

Section B (Chemistry).

Dr. J. H. Gladstone.—On Fluorescent and Phosphorescent Diamonds.

Section C (Geology).

Lieut.-Gen. C. A. McMahon, F.R.S., F.G.S., President.—President's Address—Rock Metamorphism. (See p. 458.)

Professor Grenville A. J. Cole.—The Geology of the Country in the Neighbourhood of Belfast.

Joseph Wright.—On the Marine Fauna of the Boulder-Clay.

R. J. Ussher.—Report of the Committee to Explore Irish Caves.

Dr. Henry Woodward, F.R.S.—On the Middle Cambrian Trilobites, etc., of Mount Stephen, British Columbia.

H. J. Seymour.—List of Minerals known to occur in Ireland.

Dr. C. W. Andrews.—On the Tusks and Skull of *Tetrabelodon* (*Mastodon*) *angustidens*.

Dr. Henry Woodward, F.R.S.—Report of the Committee for the Registration of Type-Specimens of British Fossils.

R. Clark.—Notes on the Fossils of the Silurian Area of North-East Ireland.

H. B. Woodward, F.R.S.—Note on the Occurrence of Bagshot Beds at Combe Pyne, near Lyme Regis.

Professor J. Joly, F.R.S.—On the Viscous Fusion of Rock-forming Minerals. (See p. 475.)

J. J. H. Teall, F.R.S.—The Drift Map of the Dublin Area.

H. Kynaston.—Note on the Volcanic Rocks of Glencoe, and their Relation to the Granite of Ben Cruachan.

James Stirling.—Notes on the new Geological Map of Victoria.

Professor J. F. Blake.—On the Original Form of Sedimentary Deposits. (See p. 473.)

Professor H. G. Seeley, F.R.S.—On Cretaceous Fossils from the Salt Range of India. (See p. 471.)

Madame Christen.—Investigations into the Glacial Drifts of the North-East of Ireland, conducted by the Belfast Naturalists' Field Club.

P. F. Kendall.—On the Brockrams of the Vale of Eden, and the Evidence they afford of an inter-Permian Movement of the Pennine Faults.

———— Report of the Committee on Erratic Blocks.

William Mackie, M.D.—The Condition under which Manganese Dioxide has been precipitated in Sedimentary Rocks.

———— The so-called Fossil Water of the Sedimentary Strata and Sandstone of the Moray Firth.

Professor Grenville A. J. Cole.—On the Geological Structure of Ireland. (See p. 456.)

R. H. Traquair, M.D., F.R.S.—On the Fishes of the Lower Devonian Roofing Slate of Gemünden, Germany.

G. Barrow.—On the Prolongation of the Highland Border Rocks into County Tyrone.

E. A. Newell Arber.—The Fossil Flora of the Cumberland Coalfield.

R. Lloyd Praeger.—The Post-glacial Deposits of the Belfast District.

A. R. Dwerryhouse.—Report of the Committee on the Movements of Underground Waters of North-West Yorkshire.

A. Smith Woodward, LL.D., F.R.S.—On a Lower Carboniferous Fish-Fauna from Victoria, Australia. (See p. 471.)

Professor W. W. Watts.—Report of the Committee for the Collection and Preservation of Geological Photographs.

H. W. Monckton.—On the Valleys at the head of the Hardanger Fjord, Norway. (See p. 476.)

——— A Summary of the Principal Changes in South-East England during Pliocene and more recent times.

A. R. Hunt.—The evidence of the Hydrothermal Metamorphism of the Schists of South Devon. (See p. 474.)

W. G. Fearnsides.—Some new Faunas from Pen Morfa near Tremadoc, North Wales.

A. K. Coomáraswámy.—Note on the Scenery of Ceylon. (See p. 476.)

Dr. Wheelton Hind.—Report of the Committee for studying Life-zones in the British Carboniferous Rocks.

W. Barlow.—Report of the Committee on the Present State of our Knowledge of the Structure of Crystals.

SECTION D (ZOOLOGY).

Dr. R. F. Scharff.—Some Remarks on the Atlantis Problem. (See p. 455.)

Dr. Henry Woodward, F.R.S. (on behalf of *Dr. C. W. Andrews, B.A., F.G.S.*).—Note on the Skull of *Mastodon angustidens.*

C. Davies Sherborn.—Index Animalium.

J. Stanley Gardiner.—The Breaking-up of Coral Rock by Organisms in the Tropics.

SECTION E (GEOGRAPHY).

Dr. H. R. Mill.—Antarctic Expeditions.

W. S. Bruce.—The Scottish National Antarctic Expedition.

Sir Clements Markham.—Note on Captain Sverdrup's North Polar Expedition.

Rev. W. S. Green.—Rockall and Porcupine Bank.

Professor W. W. Watts.—Charnwood Forest, a buried Triassic Landscape.

J. Milne, F.R.S.—World-shaking Earthquakes, with Special Reference to the Recent Volcanic Eruptions in the West Indies.

Dr. Herbertson.—Preliminary Note on the Windings of Evenlode.

Mr. Porter.—Cork Valleys.

Professor Johnson.—Peat.

Dr. Johnston.—Survey of the Scottish Lakes.

Professor Libbey (of Princeton University, N.J., U.S.A.).—The Jordan Valley.

SECTION G (ENGINEERING).

R. G. Allanson-Winn.—Material bearing Ocean Currents.

SECTION H (ANTHROPOLOGY).

W. J. Knowles.—On Objects of the Plateau kind from the Interglacial Gravels of Ireland.

——— On Stone-Axe Manufactories in Ballymena, nr. Cushendall.

——— On the Manufacture of Stone Arrowheads and Spearheads.

Miss Nina F. Layard.—On a recent discovery of Palæolithic Deposits in Ipswich.

E. Cunnington.—Palæolithic Implements from Knowle, Wiltshire.

R. M. Young.—Notes on the Excavation of a Settlement of Irish Elk-hunters at Balloo Bay, Groomsport, County Down.

SECTION K (BOTANY).

A. C. Seward, F.R.S., and E. N. Arber.—Fossil Nipa Fruits from Belgium.

Miss Margaret Benson, D.Sc. — The Seed-like Fructification of *Miadesmia membranacea* (Bertrand), a Lycopodiaceous Plant from the Coal-measures.

——— A Possible *Calymmatotheca* type of Fructification showing Structure.

James Lomax.—On some New Features in Relation to *Lyginodendron Oldhamium.*

Dr. D. H. Scott, F.R.S.—Sporangiophores as a clue to Affinities among the Pteridophyta.

Miss Sibille O. Ford.—Notes on the Morphology and Past History of the Araucarieæ.

James Lomax.—On the Occurrence of the Nodular Concretions (Coal Balls) in the Lower Coal-measures.

Professor F. W. Oliver, D.Sc.—On Ancient and Modern Seeds.

III.—FOSSILS FROM CRETACEOUS STRATA IN THE SALT RANGE. By Professor H. G. SEELEY, F.R.S., V.P.G.S.[1]

HITHERTO there has been no evidence of Cretaceous strata in the Salt Range of the North of India. But Mr. Ernest G. Fraser, formerly of the Punjab Civil Service, has found many species of the type or age of the Upper Greensand. In 1893 he crossed the Salt Range and made a collection, placed in my hands, in which are the usual Primary, Secondary, and Tertiary types indicated by Mr. Wynne. But in addition are typical Cretaceous species in limestone. Among the more abundant are *Spondylus costulatus* (Stol), *Spondylus calcaratus* (Forbes), *Hinnites andoorensis*, and *Lucina arcotina*. The specimens are in good preservation, and weathered out from the rock. They are from the shoulder of Sekasar. Mr. Fraser did not draw a section; but the fossils which are deposited in the Royal Indian Engineering College show that the section must have been similar to those given by Mr. A. B. Wynne, except that Mr. Fraser had the good fortune to find Cretaceous fossils below the Tertiary strata. This northward extension of the fossils suggests that the Indian Cretaceous sea may possibly have been continuous with that of Central Asia, though the beds described by Dr. F. Schmidt in Siberia have fossils of a Gault type which has not yet been recognised in the Salt Range of India.

IV.—PRELIMINARY NOTE ON A CARBONIFEROUS FISH FAUNA FROM VICTORIA, AUSTRALIA. By A. SMITH WOODWARD, LL.D., F.R.S., of the British Museum.[2]

THE researches of Dr. Traquair have proved that in Britain there is a definite succession of Devonian and Carboniferous fish faunas. When sufficiently well-preserved fossils are available, these faunas can be readily distinguished and recognised, and they

[1] Abstract of a paper read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

[2] Read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

always occur in the same stratigraphical order. There is also considerable evidence of a similar succession on the continent of Europe, in Spitzbergen, and in North America.

Much interest was therefore aroused, twelve years ago, when the late Sir Frederick McCoy announced that a mixture of representatives of all these different faunas had been discovered in a bed of Palæozoic Red Sandstone in Australia.[1] These fossils were found at the supposed base of the Carboniferous system in the valley of the Broken River, near Mansfield, Victoria. The first fragments were discovered by Mr. Reginald Murray; a large series of remains was afterwards collected by the Rev. A. Cresswell for the Geological Survey of Victoria; and valuable additions were also made by Mr. George Sweet, F.G.S., of Melbourne. The complete collection was placed in the Melbourne Museum, and Sir Frederick McCoy's report was the result of his preliminary study of it.

Unfortunately, notwithstanding the interest of this important discovery, no definite information concerning it has hitherto been published. Before his death McCoy was only able to supervise the drawing of some plates to illustrate a memoir which he hoped to prepare. The specimens proved to be too fragmentary, and the materials for comparison in the Australian museums too inadequate for him to arrive at any satisfactory results. The whole collection has therefore been sent to me by Professors Baldwin Spencer and J. W. Gregory; and at present I have the honour of preparing the projected memoir for the Geological Survey of Victoria.

With ample facilities for the study of the collection, it now appears that McCoy's original report was based on a complete misinterpretation of many of the fragments. Far from displaying a "mixture of Lower Devonian, Upper Devonian, and types related to some of the Calciferous Sandstone series," as McCoy supposed, the Broken River collection is typically and essentially Carboniferous; and some of the specimens are of great interest, both from the ichthyologist's and from the geologist's point of view.

None of the specimens or drawings are labelled with the names proposed for them by McCoy, and none of his manuscript notes are forthcoming. I am thus unable to recognise all his identifications with certainty. Most of them, however, are distinguishable; and it is, in any case, sure that I have the whole of the material which was at his disposal.

The fossils regarded by McCoy as Lower Devonian in facies received the names of *Rytidaspis murrayi* and *Pteraspis* (?) *mansfieldensis*. The former was said to be of the same shape as *Cephalaspis*, the latter not more than generically distinct from *Pteraspis*. There are, however, in the collection no remains either of Cephalaspidians or Pteraspidians, or any types related to them. I do not know to which fossil the name *Rytidaspis* was applied, but it is evident that impressions of some gular plates of a large Rhizodont fish were mistaken for the supposed *Pteraspis*.

[1] F. McCoy, "Report on Palæontology for the year 1888": Ann. Rep. Sec. Mines, Victoria, 1889 (1890), pp. 23, 24.

The determination of the remains, claimed to be of a later Devonian type, is equally unsatisfactory. The only Acanthodian sufficiently well preserved for discussion is not specially related to the Devonian forms, but has the elongate shape characteristic of the genera of the Carboniferous and Permian periods. The Acanthodian fragment compared with the Devonian *Cheirolepis* (which is not an Acanthodian) is too imperfect for consideration. The so-called scales of the Devonian *Glyptolepis*, or an allied genus, evidently belong to the large Rhizodont already mentioned, and closely resemble the scales of the Lower Carboniferous *Rhizodus* itself. The Australian fish, however, does not belong to the latter genus, its teeth being round in transverse section.

The most interesting of all the genera represented in the collection is one rightly recognised by McCoy as an Elasmobranch allied to the Carboniferous *Gyracanthus*. It is named *Gyracanthides*, and is a round-bodied Acanthodian fish, apparently toothless, with the comparatively small and spinous pelvic fins advanced far forwards, as in *Acanthodes*. Its dorsal fins have not been observed, but its small anal fin is armed with a spine.

There is also evidence of a small Dipnoan fish with teeth and scales like those of the Carboniferous and Permian *Sagenodus*. The typically Carboniferous Palæoniscidæ in the collection are related to *Elonichthys*.

There is thus no abnormal mingling of genera in the Early Palæozoic fish fauna from the Broken River, Victoria. It is a typical Carboniferous assemblage without any extraneous elements.

V.—On the Original Form of Sedimentary Deposits. By Rev. Professor J. F. Blake, M.A., F.G.S.[1]

IN determining the position and outline of ancient continents by observing the direction in which the sediment derived from them thickens or thins, and in interpreting the significance of the contours of the sea-bottom, it is necessary to consider what will be the actual shape as a whole of any sedimentary deposit of single origin in relation to the land whence it is derived.

It has been assumed by several authors, both of text-books and of special memoirs, that sedimentary deposits are thickest near their source of origin, and that limestones are deposited at great distances from the shore. The author gives reasons for taking a somewhat different view. The action of tides and currents is considered as a subsequent operation, the original form of the deposit is that which would result in a tideless sea, in the case of a river carrying detritus directly outwards. The coarse material, which is pushed along the bottom of a river, fills up the angle between the lowest level the river reaches and the constantly deepening bottom of the sea, and the deposit is consequently wedge-shape towards the land and sharply sloping seawards, like the tip of a railway embankment. The detritus which floats consists of all that has too low a power

[1] Abstract of a paper read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

of sinking to overcome the velocity of the stream, and only begins to sink on the retardation of that velocity. The detritus with any particular rate of sinking will thus descend faster and also be crowded into a narrower area at a distance from the shore, and so form a thicker deposit there, where alone there is permanently room for it. This result will be modified by (1) the expansion laterally of the retarded stream, (2) the evaporation of the surface water, (3) the mixture with sea-water, (4) the superposition of various maxima at different distances from shore, (5) the redistribution by tides and currents.

During the continuance of constant physical conditions the seaward boundary of river-brought deposits will thus be a marked line—the 'mud-line' of Dr. Murray—at various depths, according to circumstances. At this line there is a rapid change of slope. This has been called an escarpment, and the edge of the continental plateau, but it is suggested that it is really the limit of terrigenous deposits in bulk.

The lateral expansion of the stream divides it into two spirals on the two sides of the axis and separated by it. Along this axis the deposit will be carried farther to sea than on the two sides. This will cause an apparent depression of the sea-bottom opposite the mouths of direct rivers. These depressions have been taken to be submerged river-channels, but they are the natural result of the form of the deposit, except in special cases—of which the Congo may be one. Such depressions may be seen indicated on charts of the sea opposite suitable rivers, as on the west coast of Spain and India, and on the east coast of America.

Original organically formed limestones require not only water free from sediment, which may be found between the openings of large rivers, but an abundant supply of the organisms producing them. It is seen from the results of the *Challenger* expedition that 60 per cent. of the species of such animals, and probably a higher one of the specimens, inhabit the first 100 fathoms, and another 20 per cent. the next 100 fathoms. Limestones are, therefore, most likely to form narrow lenticles with the long axis parallel to the shore, as in the case of barrier reefs; and when we find them giving place to shales, it is not because we are approaching a shore-line, but because in going parallel to the shore-line we are approaching a source of sediment.

VI.—The Evidence of the Hydrothermal Metamorphism of the Schists of South Devon. By A. R. Hunt, M.A., F.G.S.[1]

THE author contends that a dominant cause of alteration in the Devonshire schists was the presence of water; in other words, that as the presence of some degree of heat is not disputed the metamorphism was hydrothermal. He divides the schists into two groups:—

1. Rocks which have been variously called chlorite-schists, hornblende-schists, epidote-schists—or, generally, green rocks.

[1] Abstract of a paper read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

2. Mica-schists, more or less associated with quartz-schists.

The first group are, he observes, usually attributed to the alteration of basic augitic rock; that is, they were originally composed of anhydrous minerals, pyroxenes, and felspars. He then adduces evidence to show that they now have become transformed into rock, consisting of hornblende, epidote, zoisite, and chlorite; all of which contain water of crystallisation, together with albite, which is charged with actual water. In short, he remarks that the one characteristic mineral which by way of addition distinguishes the green rocks from their assumed parents is water.

He then deals with the second group, showing a similar result. Thus, he maintains, the hydro-metamorphism of the district seems pretty well established, and he contends that whilst thermo-dynamic metamorphism is admitted in South Devon, the universal presence of water in the newly constituted rocks must compel us to assign a very important position to hydro-metamorphism as an agent of change. It is not so much that water must have been present during the metamorphic process, as that it is in the rocks now, and could not have been introduced since their crystallisation.

VII.—On the Viscous Fusion of Rock-forming Minerals. By Professor J. Joly, D.Sc., F.R.S., F.G.S.[1]

In a paper read at the Congrés Geologique International of 1900, and in a short note communicated to the British Association Meeting at Bradford, 1900, experiments on the viscous fusion of some rock-forming minerals are described by the author. It appeared that under the influence of prolonged exposure to high temperatures, rounding and other signs of fusion (a breakdown of stability as a solid) could be obtained at much lower temperatures than have hitherto been assigned as the melting-points. This lowering of the melting-point under prolonged heating (four hours) is more marked generally in the case of minerals containing a large percentage of silica, and most marked in the case of quartz. On this account the *order* of the melting-points is in general different under conditions of prolonged heating than under conditions of short exposure.

The former results, as regards melting under conditions of short exposure (results required for comparison with those obtained under conditions of long exposure), were not quite satisfactory (as at the time the author pointed out) in so far that the observations were not effected in the same manner as those under conditions of prolonged exposure. This defect in the observation has now been removed. One-minute exposures have been made of all the minerals previously dealt with on exposures of four hours, and the results confirm the former conclusions, but reveal a decreased difference in the two melting-points; in other words, the short-exposure melting-points being below previous results, the *depression* of melting-point

[1] Abstract of a paper read before the British Association, Belfast, Sept., 1902, in Section C (Geology).

upon prolonged exposure is less than formerly deduced. The depression, however, increases generally with the silica-content of the mineral, as previously observed.

VIII.—On the Valleys at the Head of the Hardanger Fjord, Norway. By Horace Woollaston Monckton, F.L.S., F.G.S.[1]

ABOVE the head of the Hardanger Fjord there is a great moorland with a level of over 2,000 feet. It is an old land-surface of at least pre-Glacial date, with rounded hills and wide shallow valleys. The plateau upon which the snowfield Hardanger Jökul lies and a few mountain tops attain a still higher level, and may, as suggested by Dr. Reusch, be remains of a far older land-surface. In the moorland deep narrow valleys have been cut, probably the result of a rise of the land before or at an early part of the Glacial period. It is suggested that the hollow in which the Hardanger Fjord lies may have been excavated at the time of this elevation.

The author traces the course of the river Bjoreia across the pre-Glacial surface to the Vöringfos (waterfall), where it plunges into the deep narrow valley Maabödal. He agrees with Dr. Reusch that the precise direction of this valley is due to lines of weakness, or cracks in the rock, and that the valley is not a fissure valley, but has been excavated by water assisted by ice.

The author was struck by the resemblance of the head of the valley at the Vöringfos to a giant's cauldron, and suggests that much of the excavating may have been the work of sub-Glacial streams when ice covered the surface. The Maabövand, a talus-dammed lake, is described. Below it the river enters the side of a wide section of the valley, and possibly the head of the valley was at one time at this point. A little below Tveit there appears once to have been a small lake formed by moraine. At Sæbö the valley unites with Hjælmodal, and some interesting terraces are described. Below is the lake Eidfjordsvand, formed by a great moraine. Dr. Brögger has shown that during the early part of the Ice-age the land stood much higher than now. Subsequently depression took place, but towards the close of that period elevation again set in, and the terraces at Sæbö and others below the Eidfjordsvand are the result of this last elevation.

IX.—Note on the Scenery of Ceylon. By A. K. Coomáraswámy, B.Sc., F.L.S., F.G.S.[1]

IT is probable that Ceylon has been exposed to continuous denudation since very early Palæozoic times. The foliation of the crystalline rocks has had a marked influence in determining the directions of the river valleys and the general configuration of the country. The foliation strike is usually from north to north-west. Many rivers have a similar direction, as examination of a map will show. A north-and-south strike-valley runs from Wattegama to Dambulla,

[1] Abstract of a paper read at the British Association, Belfast, Sept., 1902, in Section C (Geology).

followed by the railway as far as Matale. North-north-west valleys are conspicuous north of Hunasgiriya. The Mahaweli Ganga valley, south of Peradeniya, is a strike-valley; another good example is the valley running north-west from Hatton. Each of these valleys is followed by the railway. Other conspicuous north-west valleys (probably strike-valleys) are those between Kurunegala and Matale; and north-east of Adam's Peak and south of Ratnapura. A small area east of Kandy has been examined in detail, and shows a diagrammatic system of strike-valleys, with others at right angles thereto, the strike being here, however, more nearly east and west than is usually the case. The bands of limestone may have had some effect in determining the actual positions of these valleys. Of course, *all* valleys in Ceylon are not strike-valleys; thus the Mahaweli Ganga valley crosses the general strike below Gettembe (east of Peradeniya), forming a series of rapids.

A characteristic feature of the scenery of Ceylon in many parts is its precipitous character; the seemingly 'bedded' granulites form mural escarpments and dip slopes, as if they were a series of sedimentary rocks.

The above remarks apply only to the mountainous districts which occupy the south central part of Ceylon. A low coastal plain fringes the island, partly of alluvial and partly of raised beach origin; sea cliffs are absent or very unusual, and even any coast exposures of rock are not common. In the north a greater area is flat and low, and the scenery resembles that of Southern India. Isolated hills of gneiss (Dambulla, Sigiri, etc.) rise conspicuously from the plain.

X.—Short Notices.

1. Oligocene.—No. 15 of Bulletins of American Palæontology (Cornell University), 16 June, 1902, contains the thesis for Ph.D. of Carlotta Joaquina Maury. It is entitled "A comparison of the Oligocene of Western Europe and the Southern United States." Maury's conclusions are: "A comparison of the invertebrate faunas of the two continents offers but little evidence, either for or against the argument, that the Vicksburg and Chipola epochs may properly be referred to the Oligocene. Rather more European Oligocene species or their analogues occur in the American Eocene than in the so-called Oligocene beds. Some also are found in the American Miocene. Yet certain characteristic Oligocene species, or their varieties, are in the Vicksburg and Chipola beds, and as more of the Chipola species are described further similarities may be noted. This incomplete evidence, furnished by the invertebrates, is strengthened by the resemblances found by Scott and others between the vertebrate faunas of the two continents during the period."

2. The Genus *Columbella*.—Mr. S. Pace has completed his list of the described species of *Columbella*. The list, which runs to some two thousand entries, appears in the Proc. Malacol. Soc., vol. v, 1902, and is a preliminary to further study. It is an excellent example

of how to work, as it ensures the acquaintance of the author with his subject; thus standing in striking contrast to the odd and end descriptions of supposed new species, which are poured forth year after year by those who have a meagre acquaintance with literature. It would be interesting to learn how many of these 'species' are valid; perhaps thirty per cent. would be a fair estimate.

3. Polish Geology. — We call the attention of our readers to "Katalog literatury naukowej Polskiej wydawany przez Komisye Bibliograficzna Wydzialu Matematyczno-Przyrodniczego Akademii Umiejetnosci w Krakowie," of which, in part i, there is a list of all the scientific journals published in Polish. The catalogue comes out in parts, and is carried out on the lines laid down by the International Catalogue of Scientific Literature Committee.

4. Australian Tertiaries.—Messrs. Hall & Pritchard publish a suggested nomenclature for the marine Tertiary deposits of Southern Australia in the Proc. Roy. Soc. Victoria, xiv (2), April, 1902. They differ from McCoy, Tate, and Dennant in considering the Balcombian to come above the Jan Jucian and Aldingan beds.

5. Rugby School Museum.—In the Report of the Rugby School Natural History Society for 1901 (1902), a list is given by H. A. Ormerod of the local fossils now on exhibition in the Museum. After each name comes the age and the locality. With the exception of a few Rhætic forms the fossils are all from the Middle and Lower Lias.

6. Surrey Science.—The Presidential Address of Mr. Whitaker, F.R.S., to the Croydon Microscopical Club for 1901 includes a list of papers on the Geology of Surrey for some years past.

7. Stromboli. — In the Archives des Sciences Physiques et Naturelles, xii and xiii, will be found two notes by A. Brun on a geological excursion to Stromboli and a note on its Basalts. The latter paper gives an account of the fusion-point of minerals from this and other localities.

CORRESPONDENCE.

THE GEOLOGICAL SURVEY OF ENGLAND AND WALES AND THE WHITE CHALK.

Sir,—An official memoir on "The Geology of the Country around Southampton (Explanation of Sheet 315)" was received at the British Museum (Natural History) about the 28th August, 1902. In this memoir one reads the extraordinary statement "*Offaster pilula*, an echinoderm characteristic of the *Marsupite* zone" (p. 2, chap. ii, Upper Chalk). If this is true, why is there not some support given to such a statement? It has been distinctly shown by Rowe (Proc. Geol. Assoc., xvi (6), 1900, pp. 342, 363; xvii (1), 1901, pp. 55, 56, 73) that this urchin is characteristic of the *quadratus*-zone, and that its occurrence in the *Marsupites*-zone is extremely unusual.

One would have thought that enough had been said already about the zones of the Chalk, and that especial pains would therefore be taken to attain to greater exactness in official memoirs.

C. Davies Sherborn.

MARINE SHELLS.

Sir,—I beg to inform the readers of the Geological Magazine that, acting under my directions, Mr. David Nimmo, jun., and Mr. Frank White have found *marine shells* in the drift of the Leaze Burn, near the watershed with Logan Water, and four miles north-east of Muirkirk, in Ayrshire. The drift here is a yellowish Boulder-clay, the clay being very fine-grained and exceedingly suitable for preserving organisms. The exposed bed is 15 feet thick, rock not seen, and 1,330 feet above sea-level, and is the highest point in Scotland at which marine organisms have been found in the drift.

J. Smith.

Monkredding, Kilwinning.
Sept. 1, 1902.

DEVELOPMENT OF RIVERS.

Sir,—Mr. Buckman, in his article on River Development in the August number of the Geological Magazine, criticizes my paper published in the Quart. Journ. Geol. Soc., vol. lviii, p. 207. On two points his criticisms are well founded. My allusion to the Vale of Moreton, which was added after the writing of the paper, was made under a misapprehension, for I had not grasped the fact that the anticline was considered by Mr. Buckman to be of Inferior Oolite age. Under such circumstances it was of no use to me, for I was in search of an arching up of the Chalk at a much later date. It is true also that the Vale of Moreton is wrongly placed on my map. The name was added, I think, on a proof, but the responsibility, of course, was mine. As regards the other points on which Mr. Buckman considers that I have erred in matter of fact, I see no reason to modify what I wrote.

Mr. Buckman finds it very remarkable that the anticline of which I was in search should be evidenced by no more than traces. The difficulty in locating it is due to the fact that the Chalk, in which alone its effects would have been obvious, has been denuded away; that it has not been recognized in the Oolitic rocks means nothing, for it would be masked by the more pronounced movements which affected those rocks before the deposition of the Chalk, but that it existed is proved by a general consideration of the dip of such Chalk as remains. As I pointed out, the westerly rise cannot have continued indefinitely, for it would have carried the Upper Cretaceous base far above the level at which we believe it to have lain in the West of England and in Wales.

The paper by Mr. Buckman in the Proc. Cotteswold Nat., vol. xiii, p. 175, 1899–1901, which I characterized in a footnote as "transgressing the limits of legitimate speculation," was preceded, as he points out, by a paper in Natural Science, vol. xiv, p. 270, 1899.